

**INCORPORATION OF ELEPHANT FOOT YAM AS A
FUNCTIONAL INGREDIENT IN *DAHI* AND *LASSI***



**THESIS SUBMITTED TO THE
ICAR-NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
(DEEMED UNIVERSITY)**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF**

DOCTOR OF PHILOSOPHY

IN

DAIRY TECHNOLOGY

BY

ANUJ KUMAR

M.Sc. (Food Science and Technology)

**DAIRY TECHNOLOGY DIVISION
ICAR-NATIONAL DAIRY RESEARCH INSTITUTE
(DEEMED UNIVERSITY)**

KARNAL-132001 (HARYANA), INDIA

2015

Regn. No. 1030905



*DEDICATED
TO
KṚṢṢṢA,
MY FAMILY
& MY GUIDE*



INCORPORATION OF ELEPHANT FOOT YAM AS A FUNCTIONAL INGREDIENT IN *DAHI* AND *LASSI*

BY

ANUJ KUMAR

Thesis submitted to the
ICAR-National Dairy Research Institute (Deemed University)
Karnal (Haryana)
in partial fulfillment of the requirement
for the award of the degree of

**DOCTOR OF PHILOSOPHY
IN
DAIRY TECHNOLOGY**

Approved by



EXTERNAL EXAMINER



**(Dr. VIJAY KUMAR GUPTA)
MAJOR ADVISOR & CHAIRMAN**

Members of Advisory Committee

1. **Dr. Latha Sabikhi**
Head, Dairy Technology Division



6/7/15

2. **Dr. Ashish Kumar Singh**
Principal Scientist, Dairy Technology Division

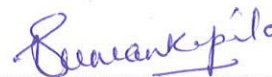


6/7/2015

3. **Dr. S. K. Tomar**
Principal Scientist, Dairy Microbiology Division



4. **Dr. Suman Kapila**
Principal Scientist, Animal Biochemistry Division



5. **Dr. Y. S. Rajput**
Former Head, Animal Biochemistry Division &
Director's nominee





DAIRY TECHNOLOGY DIVISION
ICAR- NATIONAL DAIRY RESEARCH
INSTITUTE
(DEEMED UNIVERSITY)
KARNAL -132001 (HARYANA)

Dr. Vijay Kumar Gupta
Principal Scientist

CERTIFICATE

This is to certify that the thesis entitled "INCORPORATION OF ELEPHANT FOOT YAM AS A FUNCTIONAL INGREDIENT IN *DAHI* AND *LASSI*" submitted by ANUJ KUMAR (Reg. No. 1030905), in partial fulfilment of the requirement for award of the degree of DOCTOR OF PHILOSOPHY in DAIRY TECHNOLOGY of the National Dairy Research Institute (Deemed University), Karnal (Haryana) is a bona fide research work carried out by him under my supervision and guidance and no part of the thesis has been submitted for any other degree or diploma.

Date:


Vijay Kumar Gupta
MAJOR ADVISOR & CHAIRMAN

ACKNOWLEDGEMENT

Thanks to **KR̥ṢṆA** for bestowing me with patience and strength to accomplish this endeavor.

With all sense of ecstasy I would like to thank my major advisor Dr V K Gupta for his valuable advice, benevolent guidance, critical appreciation and constant help throughout the investigation without which this work would not have seen the light of the day.

Every niche of this investigation is a beautiful conglomeration of ideas, appreciation and amalgamation of rich concepts borrowed by from my former major advisor Dr Ashok A Patel. I am highly indebted for his sapient guidance, novel ideas, constructive counsel and constant encouragement extended to me during course of investigation. Above all, his conviction in my intellect made the achievement of this goal a challenging, yet rewarding and, most significantly, an enjoyable experience for me.

I owe a profound sense of gratitude to Dr A K Srivastava, Director NDRI for providing me requisite infrastructural facilities that enabled incessant compilation of this project. I would also like to eloquent my myriads of inexpressible thanks and colossal appreciation to Dr G R, Patil, Joint Director (Acad.) and Dr S K, Kanawjia (Academic Co-ordinator), NDRI, Karnal.

Solemn regards and sincere thanks to members of my advisory committee, Dr R R B Singh, Dr (Mrs.) Latha Sabikhi, Dr Ashish Kumar Singh, Dr S K Tomar, Dr (Mrs.) Suman Kapila, Dr Y S Rajput and Dr B S Prakash for their valuable suggestions and sedulous help during planning and execution of this study.

I would like to thank Dr P N Raju, Mr Prateek Sharma, Dr Sheikh Abdul Hussain, Mr H C Devraja, Mr G S Meena, Mr Yogesh Khetra and Mr M H Sathish for their help during research. It has been my good fortune to be associated with the faculty of the Division and other Divisions of the Institute and explore my reverence gratitude to this scientist community, for their valuable suggestions, sincere encouragement, good wishes and cordial assistance in different phases of my research work.

The financial assistance provided by Department of Science and Technology, Ministry of Science and Technology, Govt. of India in form of INSPIRE-JRF and INSPIRE-SRF is thankfully acknowledged.

I am very thankful to Mr Hukum Chand, Mrs Prem Mehra, Mrs Kusum Lata, Ramswaroopji, Rampalji, Rambirji, Narender bhaiya, Keemti, Surenderji, Imtiji, Sandeepji, Zilesinhji and Jai Bhagwanji for the help rendered by them from time to time. Special thanks to Staff of Experimental Dairy, NDRI Karnal for their support during the research.

I also express my cheerful thanks to all my seniors Dr Avneet Rajoria, Dr Sangeeta Ganguly, Dr Shalini Arora, Dr Harsh Gurditta, Mrs. Nitika Goyal who offered respect and love during entire course of my stay here and will remain sparkle in my life.

My heartfelt thanks to my labmates Pola Ramakumar, Writdhama Prasad, Sanket Borad, Pravin Sawale, Mukesh Kumar, Akanksha Wadehra, Jiral Patel, Amardeep, Vivek Wankhede Patil, Richa Badola, Vidhu Yadav and Upasana Yadav for their encouragement and moral support during my study.

My heartfelt thanks to hostelmates Dr Harsh Panwar, Dr Sohan Singh, Dr Naveen, Dr Manvesh, Dr Ravinder Kaushik, Dr Narender, Dr Vijay and others.

I would like to place on record my gratitude and affection for DT friends Pankaj Parmar, Dipesh Aggarwal, Latika, Heena, Ajay Singh, Nripendra, Kunal, Apurba Giri, Zaheer, Fred, Tony, Solange, Ambar, Amol and Hind Bihari.

Words are not just enough to couch my deepest sense of reverence to my family specially, my sister for their immense love and constant encouragement, which fostered the urge to always strive for excellence.

Dated:

(Anuj Kumar)

सारांश

जिमीकंद (अमोरफोफैलस पैनोफ़ोलियस (डेन्स्ट्र.) निकोलसन) एक बहुत ही पौष्टिक, किन्तु कम दोहित कंद फसल है। यह मुख्य रूप से उष्णकटिबंधीय तथा उपोष्णकटिबंधीय क्षेत्रों में उगाई जाती है। इस कंदीय फसल को विभिन्न हिस्सों में ओल / सूरन / कंद आदि नामों से भी जाना जाता है, तथा इसका उपभोग सब्जी के रूप में किया जाता है। जिमीकंद कई प्रकार के पादप-रसायनों का अच्छा स्रोत है। जिमीकंद में मंड (१७%) अच्छे परिमाण में मिलता है तथा यह मंड एक हाइड्रो-कोलॉयड की तरह कार्य करता है। इस कंद की द्रव्य-क्रियात्मकता को किण्वित खाद्यों जैसे कि दही व लस्सी, में समाविष्ट करने का निर्णय लिया गया। जिमीकंद को उबालने से पूर्व, कई प्रकार से अवशोषित किया गया, जिससे की कंद में अंतर्निहित ऑक्सैलेट व कट्टता से निजात मिल सके। जिमीकंद को ३० मिनट उबालने से पूर्व दिए गए क्षारीय (०.०१-०.१%) अवशोषण व मंदोष्ण क्षारीय विलयन (४०-५० डिग्री सेंटीग्रेड; ०.१%) में अवशोषण ने ऑक्सैलेट के स्तर को कम किया, लेकिन जिमीकंद के संवेदी गुणों को अस्वीकार्य स्तर तक गिरा दिया। लवणयुक्त तथा अम्ली-लवणयुक्त घोल में अवशोषण भी प्रभावहीन पाया गया। उबलते हुए जल में जिमीकंद को १० मिनट तक पकाने ने उसके ऑक्सैलेट व कट्टता के स्तर को अर्थपूर्ण तरीके से कम किया। पके हुए कंद को थाली शूष्कीकरण प्रक्रिया के द्वारा विभिन्न तापमानों (५०, ६० व ७० डिग्री सेल्सियस) पर चूर्ण में परिवर्तित किया गया। अपने उच्च संवेदी गुणों तथा अल्प-पिछडक श्यानता के कारण, ६० डिग्री सेल्सियस पर कंद को सुखाने से प्राप्त हुए चूर्ण को दही और लस्सी में सम्मिश्रित करने हेतु उपयुक्त पाया गया। इस चूर्ण के विभिन्न श्लेषीकरण गुण इस प्रकार हैं: चरम श्यानता, ५४८ मि प से; विघटक श्यानता, ८० मि प से; पिछडक श्यानता, ३८० मि प से; श्लेषीकरण तापमान, ९४.१ डिग्री सेल्सियस और इस चूर्ण का श्वेतता सूचक ६९.०५ पाया गया। दही पर जिमीकंद के चूर्ण, इसबगोल तथा दूध-वसा के प्रभाव का अनुक्रिया तल कार्यप्रणाली के बॉक्स-बेहन्कन अभिकल्प द्वारा अध्ययन किया गया। अनुक्रिया तल कार्यप्रणाली के प्रयोग से प्राप्त हुए इष्टतमीकृत समाधान में, जिमीकंद चूर्ण- १.२५%, इसबगोल-०.१% तथा दूध-वसा २.१% पाये गये। इस संरूपण से प्राप्त दही संवेदी गुणों पर उपभोक्ताओं के द्वारा सराही गई। इष्टतमीकृत कंद सम्मिश्रित दही संघटन है: कुल ठोस - १३.३%, कार्बोहाइड्रेट- ५.५४%, प्रोटीन- ३.८%, वसा- ३.१%, रेशा-०.१३% तथा राख- ०.८६%। दही के जल तथा मेथनोलिक अर्क में कुल फिनाँल, डी पी पी एच तथा ए बी टी एस क्रिया-शीलता अनुगामी हैं- १.०९ μ ग्रा/ ग्रा दही चूर्ण, ०.१३ मिलीमोल टीई / ग्रा दही चूर्ण, २.०८ मिलीमोल टीई/ ग्रा दही चूर्ण तथा २.१८ μ ग्रा/ ग्रा दही चूर्ण, ०.३१ मिलीमोल टीई/ ग्रा दही चूर्ण, २.२८ मिलीमोल टीई / ग्रा दही चूर्ण। इष्ट-तिकृत दही को फिर मीठी व नमकीन लस्सी में परिष्कृत किया गया। गुलाब-सुगंधित लस्सी जिसमें तनूकरण ३७.५% तथा नमकीन लस्सी जिसमें तनूकरण ४४.४% था, को संवेदी गुणों पर सबसे अधिक वरीयता दी गई। जिमीकंद युक्त दही की ताक अवधि, सादी दही के समान पाई गई। जिमीकंद चूर्ण के समावेशन से, संवेदी रूप से स्वीकार्य वसा-घटित दही प्राप्त हुई जिसके संरचनात्मक गुण परिवर्तित तथा पादप-रसायनिक मान में वृद्धि थी।

ABSTRACT

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is a nutritious but underutilized tuber crop, which is widely grown in tropical and subtropical zones. Commonly known as *Jimmikand/ Ol/ Suran/ Kanda* and used as vegetable, this crop contains wide range of phytochemicals. Apart, this tuber is also a good source of starch (approx. 17%), which acts as a hydrocolloid. In this project, the dual-functionality of this tuber was incorporated in fermented foods viz. *dahi* and *lassi*. The elephant yam was treated with various pre-soaking and cooking combinations to remove the inherently present oxalate and / or acidity problem. Various pre-soaking treatments i.e. pre-soaking in warm (40-50°C) 0.1% NaOH solution or alkali soaking (0.01-0.1%) followed by 30 min cooking, caused some reduction in oxalate levels, but at the same time made elephant foot yam sensorially unacceptable. Even saline and acidulated saline soaking followed by cooking resulted in unacceptable sensory quality of elephant foot yam. Further cooking in boiling water for 10 min caused significant ($p \leq 0.01$) reduction in oxalate and acidity levels. Cooked yam (10 min) was then tray dried at different temperatures (50°C, 60°C and 70°C). On account of better sensory acceptability and low setback viscosity, the elephant yam dried at 60°C was observed to be suitable for addition in *dahi* and *lassi*. Cooking elephant foot yam for 10 min followed by tray drying at 60°C was used for blending into milk for the preparation of *dahi*. The dried elephant yam possessed following pasting attributes: peak viscosity, 548 mPa.s; breakdown viscosity, 80 mPa.s; setback viscosity, 380 mPa.s; pasting temperature, 94.1°C and had a whiteness index of 69.05. Yam powder, along with various levels of psyllium and milk fat, was studied for *dahi* making using Box-Behnken design of Response Surface Methodology. The optimized solution for *dahi* making, as obtained from RSM, had 1.25% yam solids, 0.15% psyllium and 2.1% milk fat. The *dahi* obtained with above formulation was sensorially well accepted by consumers. The optimized yam-blended *dahi* had 13.30% TS including 5.54% carbohydrates, 3.8% protein, 3.1% fat, 0.13% fibre and 0.86% ash. The total phenolic content, DPPH, ABTS activity of water and methanolic extract per g yam dahi, on dry matter basis, were 1.09 mg GAE, 0.13 μ mole TE, 2.08 μ mole TE and 2.18 mg GAE, 0.31 μ mole TE, 2.28 μ mole TE, respectively. The optimized *dahi* was further processed to *lassi*, both sweet and salted. The rose-flavoured sweet *lassi* with dilution level of 37.5% (600 g water per kg *dahi*) and salted *lassi* with dilution level of 44.4% (800 g water per kg *dahi*) was sensorially most preferred. The storage life of yam blended *dahi* was observed to be similar to plain *dahi*. It was concluded that the incorporation of elephant foot yam powder resulted in sensorially well acceptable lower-fat (2.1%) *dahi*, having desired modified textural attributes and enhanced phytochemical attributes.

TABLE OF CONTENTS

Chapter No.	Title	Page No.
1.0	INTRODUCTION	1-4
2.0	REVIEW OF LITERATURE	5-26
	2.1	Elephant foot yam
	2.1.1	Production
	2.1.2	Botanical Description
	2.1.3	Composition of Elephant Foot Yam
	2.1.4	Medicinal Properties and Health Benefits
	2.1.4.1	<i>Antimicrobial activity</i>
	2.1.4.2	<i>Analgesic activity</i>
	2.1.4.3	<i>Hepato-protective activity</i>
	2.1.4.4	<i>Medicinal uses</i>
	2.1.5	Culinary Uses of Elephant Foot Yam
	2.2.	Acridity problem in elephant foot yam
	2.2.1	Calcium Oxalate as Agent of Acridity
	2.2.2	Solutions to the Acridity and/or Oxalate Problem
	2.2.2.1	<i>Non-acrid varieties</i>
	2.2.2.2	<i>Traditional Processing Methods</i>
	2.2.2.3	<i>Bacterial degradation and Fermentation</i>
	2.2.2.4	<i>Cooking Processes</i>
	2.3	Fermented dairy foods
	2.3.1	<i>Dahi</i>
	2.3.2	<i>Lassi</i>
	2.3.3	Vegetables in fermented dairy products
	2.3.4	Starch in fermented dairy products
	2.3.4.1	<i>Effect of starch addition on characteristics of fermented dairy products</i>

3.0	MATERIALS AND METHODS		27-52
	3.1	Materials	27
	3.1.1	Elephant Foot Yam	27
	3.1.2	Buffalo Milk	27
	3.1.3	Skim Milk Powder	27
	3.1.4	Psyllium Husk	28
	3.1.5	Packaging Material	28
	3.1.6	Starter Culture	28
	3.1.7	Salt, spices and sugar	28
	3.1.8	Flavour	28
	3.1.9	Chemicals	29
	3.2	Methodology	29
	3.2.1	Pre-soaking treatment study of elephant foot yam	29
	3.2.2	Alkaline pre-soaking using response surface methodology	29
	3.2.3	Pre-soaking and cooking of elephant foot yam under alkaline conditions produced by NaHCO ₃	32
	3.2.4	Cooking of elephant foot yam in boiling water	33
	3.2.5	Drum drying of cooked elephant foot yam	34
	3.2.6	Spray drying of cooked elephant foot yam	34
	3.2.7	Tray drying of cooked elephant foot yam	34
	3.2.8	<i>Dahi</i> blended with elephant foot yam	36
	3.2.9	Sweetened and flavoured <i>lassi</i> blended with elephant foot yam	37
	3.2.10	Salted and spiced <i>lassi</i> blended with elephant foot yam	38
	3.2.11	Storage of <i>dahi</i> blended with elephant foot yam	40

	3.3	Analytical procedures	41
	3.3.1	Physical Parameters	41
	3.3.1.1	<i>Instrumental colour analysis (Hunter L*, a* and b* values)</i>	41
	3.3.1.2	<i>Sedimentation</i>	41
	3.3.1.3	<i>pH</i>	42
	3.3.1.4	<i>Bulk density, true density and porosity</i>	42
	3.3.1.5	<i>Browning Index</i>	42
	3.3.1.6	<i>Water absorption index and water solubility index</i>	42
	3.3.1.7	<i>Oil absorption index</i>	43
	3.3.1.8	<i>Pasting properties</i>	43
	3.3.1.9	<i>Water holding capacity</i>	44
	3.3.1.10	<i>Syneresis</i>	45
	3.3.1.11	<i>Textural analysis</i>	45
	3.3.2	Chemical Parameters	46
	3.3.2.1	<i>Oxalate (total and soluble) content</i>	46
	3.3.2.2	<i>Solids loss</i>	47
	3.3.2.3	<i>Proximate composition</i>	47
	3.3.2.4	<i>Total phenol and DPPH activity of yam paste</i>	48
	3.3.2.5	<i>Total phenolic content, DPPH and ABTS activity of yam powder</i>	50
	3.3.3	Sensory Evaluation	51
	3.3.3.1	<i>Sensory evaluation of yam-milk mix</i>	51
	3.3.3.2	<i>Hand sensed acidity of yam paste</i>	51
	3.3.3.3	<i>Sensory evaluation of dahi and lassi</i>	52
3.3.4	Consumer response study and cost analysis of yam-dahi	52	
3.3.5	Statistical analysis	52	
4.0	RESULTS AND DISCUSSIONS		53-155
	4.1	Processing of elephant foot yam to make it compatible in dairy foods	53

	4.1.1	Effect of alkaline pre-soaking on properties of cooked EFY and EFY-milk mix	54
	4.1.1.1	<i>Effect of alkaline soaking (NaOH) treatment on Hunter colour parameters (L^*, a^*, b^*) and whiteness index (WI) of paste obtained from pre-soaked and cooked EFY</i>	54
	4.1.1.2	<i>Effect of alkaline (NaOH) pre-soak on oxalate content and hand-sensed acidity of cooked EFY paste</i>	57
	4.1.1.3	<i>Effect of alkali pre-soaking of EFY on sedimentation in yam-milk dispersion obtained by blending pre-soaked and cooked EFY with milk</i>	59
	4.1.1.4	<i>Sensory characteristics of yam-milk mix prepared from alkali-pre-soaked, cooked yam</i>	60
	4.1.2	Effect of saline pre-soaking on properties of cooked EFY and EFY-milk mix	62
	4.1.2.1	<i>Effect of saline pre-soaking on Hunter colour parameters (L^*, a^*, b^*) and whiteness index (WI) of cooked yam paste</i>	62
	4.1.2.2	<i>Effect of saline pre-soak on the oxalate content and hand-sensed acidity of cooked EFY paste</i>	66
	4.1.2.3	<i>Effect of saline pre-soaking on sedimentation in yam-milk dispersion obtained by blending pre-soaked and cooked EFY with milk</i>	69
	4.1.2.4	<i>Sensory characteristics of yam-milk mix prepared from saline-pre-soaked,</i>	69

		<i>cooked yam</i>	
4.1.3		Effect of acidulated saline pre-soaking (pH 3.5) followed by plain-water cooking on properties of EFY and yam-milk mix	73
4.1.3.1		<i>Effect of acidulated saline soaking treatment on Hunter colour parameters (L^*, a^*, b^*) and whiteness index (WI) of the yam paste</i>	73
4.1.3.2		<i>Effect of acidulated salt soaking treatment on oxalate content and hand-sensed acidity score of paste obtained from pre-soaked and cooked EFY</i>	77
4.1.3.3		<i>Effect of acidulated saline pre-soaking of EFY on sedimentation in yam-milk dispersion obtained by blending pre-soaked and cooked EFY with milk</i>	78
4.1.3.4		<i>Sensory attributes of yam-milk mix prepared from acidulated saline pre-soaked and cooked yam</i>	78
4.1.4		Effect of alkaline pre-soaking temperature and time on the properties of elephant foot yam using response surface methodology (RSM)	82
4.1.4.1		<i>Effects of pre-soaking time and temperature on soluble oxalate content of elephant foot yam</i>	83
4.1.4.2		<i>Effect of pre-soaking time and temperature on the total oxalate content of elephant foot yam</i>	84
4.1.4.3		<i>Effect of alkaline pre-soaking conditions on sensory acidity score of elephant foot yam</i>	85
4.1.4.4		<i>Effect of pre-soaking time and</i>	88

		<i>temperature on Hunter color parameters and whiteness index (WI) of elephant foot yam</i>	
	4.1.4.5	<i>Effect of alkaline soaking variables on the pH of EFY dispersion</i>	90
	4.1.4.6	<i>Effect of pre-soaking factors on total solids in soak water</i>	90
	4.1.4.7	<i>Effect of alkali soaking on the sensory attributes of elephant foot yam</i>	92
	4.1.5	<i>Effect of pre-soaking in NaHCO₃ solution followed by cooking of EFY upon its acidity and / or oxalate</i>	94
	4.1.6	<i>Cooking of elephant foot yam in boiling water</i>	95
	4.1.6.1	<i>Effect of boiling duration on whiteness index (derived from Hunter colour parameters L*, a* and b*) of EFY paste obtained after cooking in water</i>	96
	4.1.6.2	<i>Effect of boiling duration on yam solids loss in water used as the cooking medium</i>	96
	4.1.6.3	<i>Effect of boiling duration on phenolic content and anti-oxidative activity of EFY</i>	98
	4.1.6.4	<i>Effect of boiling duration on oxalate content (soluble and total) of EFY</i>	100
	4.1.6.5	<i>Effect of boiling duration on sensory colour and acidity score of EFY and softness score of EFY cubes</i>	101
	4.1.7	<i>Drying of Cooked Elephant Foot Yam</i>	102
	4.1.7.1	<i>Drum drying of cooked elephant foot yam</i>	102
	4.1.7.2	<i>Spray drying of cooked elephant foot yam</i>	104

	4.1.7.3	<i>Tray drying of cooked elephant foot yam</i>	104
	4.1.7.3.1	Physical properties of yam powder viz. whiteness index (WI), browning index (BI), bulk density (BD), true density (TD) and porosity as influenced by tray drying temperature	105
	4.1.7.3.2	Physical functional properties of yam powder viz. water absorption index (WAI), water solubility index (WSI), oil absorption index (OAI) and pasting characteristics as influenced by tray drying temperature	107
	4.1.7.3.3	Effect of the tray drying temperature on the phytochemical content (soluble and total oxalate, phenolic content and antioxidant activity) of the powdered yam	113
	4.1.7.3.4	Influence of drying temperature on sensory attributes (flavour and mouthfeel) of yam-milk dispersion prepared from elephant foot yam powder	117
	4.2	Properties of <i>dahi</i> and <i>lassi</i> blended with elephant foot yam	117
	4.2.1	Sensory properties of <i>dahi</i> as influenced by process variables	118
	4.2.2	Whiteness index and water holding capacity of <i>dahi</i> as influenced by the process variables	127
	4.2.3	Instrumental texture parameters of yam-added <i>dahi</i> as influenced by the process variables	132
	4.2.4	Selection of the optimized process variables for the preparation of <i>dahi</i>	138
	4.2.5	Compositional analysis of <i>dahi</i> from the optimized formulation	141
	4.2.6	<i>Lassi</i> obtained from optimized <i>dahi</i>	141

	4.2.6.1	<i>Sweet lassi</i>	141
	4.2.6.2	<i>Salted lassi</i>	144
4.3	Storage of <i>dahi</i> blended with elephant foot yam		145
	4.3.1	Influence of storage on physical properties of <i>dahi</i>	146
	4.3.2	Storage-induced changes in certain texture properties of <i>dahi</i>	147
	4.3.3	Influence of storage period on sensory attributes of <i>dahi</i>	149
4.4	Consumer response study of yam-<i>dahi</i>		153
4.5	Cost of production for yam-<i>dahi</i>		153
4.5.1	Basic assumptions for cost estimation		154
4.5.2	Detailed break-up of total cost of yam <i>dahi</i>		154
5.	SUMMARY AND CONCLUSION		156-161
5.1	Effect of alkaline, saline and acidulated saline pre-soaking followed by cooking treatment of elephant foot yam on its acidity and/ or oxalate		157
5.2	Effect of warm alkali pre-soaking treatment of elephant foot yam on its oxalate content		157
5.3	Effect of pre-soaking in NaHCO₃ solution followed by cooking of elephant foot yam upon its acidity		158
5.4	Effect of cooking of elephant foot yam in boiling water on its oxalate content		158
5.5	Standardization of drying of elephant foot yam		158
5.6	<i>Dahi</i> and <i>lassi</i> blended with elephant foot yam		159
5.7	Storage study of yam containing <i>dahi</i>		160
5.8	Consumer Response and Cost of Production		160
5.9	Conclusions		160
5.10	Suggestions for future research		161
BIBLIOGRAPHY			i-xxviii
ANNEXURE (1-11)			a-k

LIST OF FIGURES

Figure No.	Caption	Page No.
Fig. RL1	Elephant foot yam	6
Fig. RL2	Raphide idioblast	12
Fig. RL3	Druse and raphide present in plant cell	13
Fig. RL4	Brake surface of fresh taro samples showing druses and raphide idioblasts projecting into intercellular space in corm	14
Fig. RL5	Flow chart depicting preparation acid free Araceae flour	16
Fig. MM1	Flow chart for preparation of pre-soaked cooked elephant foot yam	30
Fig. MM2	Flow chart for preparation of alkali pre-soaked elephant foot yam	32
Fig. MM3	Flow chart for preparation of cooked elephant foot yam	33
Fig. MM4	Process flow chart for drum/ spray drying of elephant foot yam	35
Fig. MM5	Process flow chart for preparation of cooked-yam powder	36
Fig. MM6	Process flow chart for the preparation of yam <i>dahi</i>	39
Fig. MM7	Process flow chart for preparation of sweetened flavoured <i>lassi</i>	40
Fig. MM8	Process flow chart for preparation of salted and spiced <i>lassi</i>	40
Fig. MM9	Hunter Colorflex 45/0 measurement system	41
Fig. MM10	Rapid Visco Amylograph (RVA-4) measurement system with waterbath	44
Fig. MM11	Typical RVA pasting profile showing the significant points during heating and cooling of flour/starch sample	44
Fig. MM12	Texture analyzer (TA-XT2i) with P25 aluminium probe	45
Fig. MM13	Typical force deformation curve of <i>dahi</i> in single compression mode	46
Fig. MM14	Gallic acid standard curve for estimation of total phenolic content	49
Fig. MM15	Trolox standard curve by DPPH method	49
Fig. RD1	Response surface plots of (a) soluble oxalate content (mg/ 100 g) and (b) total oxalate content (mg/ 100 g) as a function of alkaline pre-soaking time (h) and temperature (°C)	88
Fig. RD2	Response surface plots of (a) whiteness index, (b) total solids in soak water (TS) and (c) pH; as function of time	91

	(h) and temperature (°C)	
Fig RD3	Response surface plots of firmness score as a function of elephant foot yam solids (EFYS)(%), psyllium (PSY)(%) and milk fat (MF)(%)	121,122
Fig RD4	Response surface plots of consistency score as a function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)	125
Fig RD5	Response surface plots of mouthfeel score as a function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)	126
Fig RD6	Response surface plots of flavor score as a function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)	128
Fig RD7	Response surface plots of whiteness index of <i>dahi</i> as function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)	131, 132
Fig. RD8	Response surface plots of water holding capacity of <i>dahi</i> as a function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)	133
Fig RD9	Response surface plots showing firmness (N) as a function of elephant yam solids (EFYS)(%) and psyllium (PSY)(%)	135
Fig RD10	Response surface plots showing work of shear (Ns) as a function of elephant yam solids (EFYS) (%), psyllium (PSY)(%) and milk fat (MF)(%)	136
Fig RD11	Response surface plots showing work of adhesion (Ns) as function of elephant yam solids (EFYS) (%), psyllium (PSY)(%) and milk fat (MF)(%)	138
Fig. RD12	Response surface plots showing stickiness (N) as function of elephant yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)	139

LIST OF TABLES

Table No.	Title	Page No.
Table RL1	Composition of elephant foot yam	7
Table RL2	Minerals found in different cultivars of elephant foot yam	8
Table RL3	Ayurvedic properties of elephant foot yam	10
Table RL4	Nutrient composition of <i>Gajendra</i> cultivar of elephant foot yam	15
Table RL5	Desirable quality attributes of <i>dahi</i>	20
Table RL6	Indian standards requirements for <i>dahi</i>	20
Table MM1	Coded and actual values of the process variables in the RSM experiment	31
Table MM2	Design matrix for two independent variables i.e. time and temperature for RSM experiment using CCRD design	31
Table MM3	Box-Behnken RSM design for three independent process variables	38
Table RD1	Hunter L* value of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	55
Table RD2	Hunter a* value of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	55
Table RD3	Hunter b* value of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	55
Table RD4.	Whiteness value (or, Whiteness Index, WI) of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min	56
Table RD5	ANOVA for changes in Hunter colour parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in NaOH solution of different concentrations for varying periods	57
Table RD6.	Oxalate content (mg/ 100 g) of EFY paste obtained from yam pre-soaked in NaOH solution of different concentrations for varying periods and then cooked for 30 min in boiling water	58

Table RD7.	Hand-sensed acidity score of EFY paste obtained from yam pre-soaked in NaOH solution of different concentrations for varying periods and then cooked for 30 min in boiling water	58
Table RD8.	ANOVA for changes in oxalate content, hand-sensed acidity score of cooked EFY (30 min boiling) paste and sedimentation in yam-milk dispersion obtained from EFY pre-soaked in NaOH solution of different concentrations for varying periods	59
Table RD9	Sedimentation of the EFY-milk dispersion from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time	60
Table RD10	Sensory colour and appearance score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time	61
Table RD11	Sensory flavour score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time	62
Table RD12	Sensory acidity score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time	62
Table RD13	Sensory mouthfeel score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time	63
Table RD14	Hunter L* value of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	63
Table RD15	ANOVA for changes in sensory parameters of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time	64
Table RD16	Hunter a* value of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	64
Table RD17	Hunter b* value of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	65

Table RD18	Whiteness index of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	65
Table RD19	ANOVA for changes in Hunter colour parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in saline solution of different concentrations for varying periods	67
Table RD20	Oxalate content (mg/ 100 g) of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min	68
Table RD21	Hand-sensed acidity score of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	68
Table RD22	ANOVA for changes in oxalate content, hand-sensed acidity score of cooked EFY (30 min boiling) paste and sedimentation in yam-milk dispersion obtained from EFY pre-soaked in salt solution of different concentrations for varying periods	70
Table RD23	Sedimentation of the EFY-milk dispersion from EFY pre-soaked and cooked under different treatment combination of saline concentration and time	71
Table RD24	Sensory colour and appearance score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of saline concentration and time	71
Table RD25	Sensory flavour score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of saline concentration and time	71
Table RD26	ANOVA for changes in sensory parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in saline solution of different concentrations and for varying periods	72
Table RD27	Sensory acidity score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time	73
Table RD28	Sensory mouthfeel score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration	73

	and time	
Table RD29	Hunter L* value of EFY paste of the yam pre-soaked in acidulated saline solution of different concentrations for varying periods followed by cooking for 30 min	74
Table RD30	Hunter a* value of EFY paste of the yam pre-soaked in acidulated saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	74
Table RD31	Hunter b* value of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min	75
Table RD32	Whiteness index of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water	75
Table RD33	ANOVA for changes in Hunter colour parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in acidulated saline solution of different concentrations for varying periods	76
Table RD34	Oxalate content (mg/ 100 g) paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min	77
Table RD35	Hand-sensed acidity score of paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min	77
Table RD36	Sedimentation of the EFY-milk dispersion from EFY pre-soaked and cooked under different treatment combination of salt concentration and time	78
Table RD37	ANOVA for changes in oxalate content, hand-sensed acidity score of cooked EFY paste and sedimentation in yam-milk dispersion obtained from EFY pre-soaked in acidulated saline solution	79
Table RD38	Sensory colour score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time	80
Table RD39	Sensory flavour score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time	80
Table RD40	Sensory mouthfeel score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration	80

	and time	
Table RD41	Sensory acidity score of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time	81
Table RD42	ANOVA for changes in sensory parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in acidulated saline of different salt concentrations and for varying periods	81
Table RD43	Values of various responses observed after RSM experimental runs	86
Table RD44	Regression coefficients and ANOVA of fitted models for, total oxalate, soluble oxalate, acidity score, Hunter colour parameters (L*, a*, b*), whiteness index, pH and total solids in soak water	87
Table RD45	ANOVA for changes in sensory responses of paste obtained from water and alkali pre-soaked	92
Table RD46	Sensory scores of yam paste as affected from water and alkali (NaOH) pre-soaked EFY	93
Table RD47	Properties of EFY pre-soaked and cooked under alkaline conditions	95
Table RD48	Hunter colour values (L*, a* and b*) and sensory acidity score for elephant foot yam subjected to alkaline pre-soaking and cooking	95
Table RD49	Whiteness index of EFY paste obtained after cooking in boiling water and solids loss in soak water	97
Table RD50	ANOVA for changes in some physico-chemical and sensory responses of EFY paste obtained after boiling yam in water for different durations	97
Table RD51	Total phenolic content and DPPH radical scavenging activity of EFY cooked in boiling water for different periods	99
Table RD52	Oxalate (total oxalate and soluble oxalate) content of EFY paste obtained after cooking in boiling water	100
Table RD53	Sensory colour, acidity and softness scores of boil-cooked EFY paste as affected by the cooking	102
Table RD54	Effect of total solids in EFY-water slurry on drum drying	103
Table RD55	Effect of total solids in EFY-milk slurry on drum drying	104
Table RD56	Whiteness index and browning index of tray dried elephant foot yam	105
Table RD57	Bulk density, true density and porosity of tray dried	107

	elephant foot yam	
Table RD58	Water absorption index, water solubility index and oil absorption index of tray dried elephant foot yam	108
Table RD59	Pasting characteristics of tray dried elephant foot yam	110
Table RD60	Soluble oxalate content and total oxalate content tray dried elephant foot yam	113
Table RD61	Phenolic content present in powder tray dried elephant foot yam	115
Table RD62	DPPH scavenging activity of tray dried elephant foot yam	115
Table RD63	ABTS activity of tray dried elephant foot yam	115
Table RD64	Flavour and mouth-feel scores of yam-milk mix of tray dried elephant foot yam	117
Table RD65	Box-Behnken RSM design for three independent process variables at three levels each	119
Table RD66	Sensory attributes of <i>dahi</i> manufactured as per the Box-Behnken design of response surface methodology	120
Table RD67	Coefficients of quadratic models for the sensory properties of <i>dahi</i> as a function of process variables	122
Table RD68	Whiteness index and water holding capacity of <i>dahi</i> manufactured as per the Box-Behnken design of response surface methodology	129
Table RD69	Coefficients of quadratic models for the whiteness index and water holding capacity of <i>dahi</i> as a function of process variables	130
Table RD70	Texture attributes of <i>dahi</i> prepared as per the 3-factor RSM experiment (Box-Behnken design)	134
Table RD71	Coefficients of linear multiple regression equations for the instrumental texture properties of <i>dahi</i> at 5°C as a function of process variables	135
Table RD72	Goals set for constraints to get an optimum combination of the <i>dahi</i> -making variables	140
Table RD73	Optimized solution for <i>dahi</i> -making variables	140
Table RD74	Predicted and observed response values for optimized <i>dahi</i>	141
Table RD75	Composition of yam-added <i>dahi</i>	142
Table RD76	Sensory scores of sweet <i>lassi</i>	143
Table RD77	Sensory scores of sweet <i>lassi</i> as affected by different flavourings	144
Table RD78	Sensory scores of salted <i>lassi</i>	145
Table RD79	Influence of storage time on whiteness index, water	148

	holding capacity, syneresis and pH of plain and elephant foot yam solids blended <i>dahi</i>	
Table RD80	Texture parameters of plain and yam-added <i>dahi</i> during storage at 6±1°C	150
Table RD81	Sensory scores of stored plain and yam-containing <i>dahi</i>	152
Table RD82	Consumer response for yam <i>dahi</i>	153
Table RD83	Detailed break-up cost for the manufacture of yam <i>dahi</i>	155

LIST OF ABBREVIATIONS

Symbol/ Short form	Full form
<i>et al.</i>	et alii (and others)
etc.	et cetera (and other things)
CTCRI	Central Tuber Crops Research Institute
EFY	elephant foot yam
t ha ⁻¹	ton per hectare
mg	milligram
g	gram
kDa	kilo Dalton
kJ	Kilo Joule
%	per cent
LAB	lactic acid bacteria
LA	lactic acid
@	at the rate
CCP	colloidal calcium phosphate
Pa s	Pascal second
MTS	modified tapioca starch
CMC	carboxy methyl cellulose
ATS	amylomaltase treated starch
w/v	weight by volume
w/w	weight by weight
viz.	videlicet (namely)
°C	degree Celsius
NCDC	National Collection of Dairy Cultures
RSM	Response surface methodology
CCRD	Central composite rotatable design
h	hour
var.	variety
PSY	psyllium

MF	milk fat
psi	pounds per square inch
ml	millilitre
SNF	solid non fat
μ	micro
ANOVA	analysis of variance
HSD	honestly significant difference
WI	Whiteness index
BI	Browning index
min	minute
p	probability value
S	significant
NS	non-significant
TEAC	Trolox equivalent antioxidant capacity
GAE	Gallic acid equivalent
TS	Total solids

CHAPTER - 1

Introduction

1. INTRODUCTION

In modern-day societies, health is one of the central values, which are primarily focused upon. Healthy attributes of foods are prime theme in various organizational or governmental initiatives. The fast moving lifestyle of today's environment has burdened us with huge amount of stress, which is taking a toll on our mind and body. Due to upsurge in various diseases like coronary heart disease, diabetes, ageing etc., there is a continual demand for foods with enhanced functionality, which can be handy against many diseases either through preventive or recuperative effect. Functional products are a new variety of foods that promise targeted improvement in physiological functions in the body (Diplock *et al.* 1999). In these foods, particular components are directly connected with well-defined physiological effects and the health benefit is linked to a single product. Functionality creates a novelty in the food without necessarily changing the sensory quality of the product (Urula, 2004). The importance of functional foods, nutraceuticals and other natural health products has been well recognized in connection with health promotion, disease risk reduction and reduction in health care costs.

With its strong tradition of eating healthy foods, India is a potential market for functional foods. Recent market surveys show that in India, there is a great scope for value added as well as health promoting food products (Singh, 2007). Fermented foods are of great significance, since they provide and preserve vast quantities of nutritious foods in a wide varieties of flavours, aromas and textures. Around 9.1% of total milk produced in India is converted to *dahi* and this sector is showing annual growth rate of more than 20% per annum (Sheth, 2009). Consumption of fermented milks has increased significantly around the world and nowadays, various popular ingredients of functional significance are being incorporated into cultured dairy products to enhance their market value (Chandan, 1999). Owing to expanding market share and size of dairy companies, there has been a reduction of clearly structured markets i.e. merging of dairy products and fruit beverage markets with introduction of '*juiceceuticals*' like fruit-yogurt beverages that are typical examples of hybrid dairy products offering health, flavour and convenience. Another potential growth area for fermented milks includes added-value products, such as low calorie and reduced-fat

varieties and those fortified with physiologically active ingredients including fibers, phytosterols, omega-3-fatty acids, whey based ingredients, antioxidants, vitamins, and isoflavones that provide specific health benefits beyond basic nutrition. World over, efforts have been devoted to develop fermented milks containing certain non-conventional food sources such as soybeans and millets and convert them to more acceptable and palatable form, thus producing low-cost nutritious fermented foods especially for developing and underdeveloped nations, where malnutrition exists (Khurana and Kanawjia, 2007). Plant derived foods such as wines, fruits, nuts, vegetables, grains, legumes, spices, etc. exert some beneficial effects on human health. The capacity of some plant-derived foods to reduce the risk of chronic diseases has been associated, at least in part, to the occurrence of non-nutrient secondary metabolites (phytochemicals) that have been shown to exert a wide range of biological activities.

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson), an important but underutilized vegetable tuber crop of family Araceae (Aroids), is indigenous to tropical Asia. It resembles the foot of an elephant and thereby gets its name. It is a perennial herb with rounded large corm tuber, which grows underground. The crop is grown in an area of 32,000 ha producing 6.7 lakh tonnes with a productivity of 21t ha⁻¹ (CTCRI, 2010). It is mostly consumed either as a vegetable, pickle or chutney. It is good source of carbohydrate particularly starch, certain minerals (calcium, phosphorus, iron, potassium) and vitamins (vitamin A, thiamine, niacin, riboflavin). In addition, it contains a wide range of phytochemicals viz., phenols, flavonoids, and glycosides. Its medicinal properties are well recognized in Ayurveda. It is used in treatment of piles, tumours, enlargement of spleen, asthma, rheumatism and abdominal pain. Its tuberous root extract has been reported to have antibacterial (Khan *et al.* 2008, 2009), anti-oxidative, hepatoprotective (Jain *et al.* 2009), anthelmintic (Ramalingam *et al.* 2010) and analgesic activities (Dey *et al.* 2010). The presence of oxalates, which are responsible for acrid sensation in throat and mouth on consumption of yam and lack of knowledge amongst people regarding its value and processing, has contributed towards gross underutilization of elephant foot yam. The development of various non-acrid or low-acrid cultivars of foot yam, such as *Gajendra*, *Sree Padma* and *Bidhan Kusum*, improved its crop culturing techniques and improved strategies of its disease and pest management by

different research institutions, notably Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram and its Regional Stations/ Project Directorates. It has paved the way for the extensive cultivation and marketing of this crop.

Since consumption of functional foods containing nutraceuticals is being highly encouraged, fermented milks produced with incorporation of such ingredients with health benefits could be of potential interest to food industry. *Dahi* and *lassi* being important cultured dairy products, are consumed regularly as a part of diet in different parts of India, Lactic fermentation improves the digestibility of milk constituents and such products are more suitable by lactose intolerant people. Their consumption is further linked to reduced risk of heart ailments and increased number of lymphocytes in blood that fight back the disease causing bacteria (Sinha and Sinha, 2000).

Deviations in consistency and/ or expulsion of serum (syneresis) are frequently encountered problems associated with *dahi*. Hydrocolloids such as starch, etc. are commonly used to combat these problems. Added starch, not only decreases whey separation (Williams *et al.* 2004; Ares *et al.* 2007), but also improves the mouthfeel (Everett and McLeod, 2005; Alting *et al.* 2009), increase the firmness (Sandoval-Castilla *et al.* 2004) and consequently a high shear consistency and it further provides fat replacement (Amaya-Llano *et al.* 2008).

Fermented foods are an excellent medium to generate an array of products that fit into the consumer demand for health based foods. These fermented dairy products can serve as a carrier, through which elephant foot yam can potentially be consumed and its various functional and therapeutic benefits can be made use of. Also, incorporation of elephant foot yam as a source of starch--it contains 17% starch--in these foods can enhance its appeal and palatability through textural modifications, and thereby have a positive impact on the crop's consumption pattern. It would thus contribute towards enhanced economic returns to the growers of elephant foot yam. The promise lies in the possibility of starch-rich yam to provide a viable option to tailor the textural properties of these products in a desirable manner.

In view of the aforementioned facts, the present study entitled **'Incorporation of elephant foot yam as a functional ingredient in *dahi* and *lassi*'** was proposed with the following objectives:

- To study the processing of elephant foot yam to make it compatible in dairy foods.
- To study the properties of fermented dairy foods viz. *dahi* and *lassi* blended with yam powder.
- To evaluate the cultured product containing elephant foot yam for shelf life.

CHAPTER - 2

Review of Literature

2. REVIEW OF LITERATURE

The present chapter reports the literature reviewed before, while planning and execution of the present study. It includes the relevant information about elephant foot yam (EFY), oxalate and acidity with their repercussions and methods for removing the oxalate and acidity problem. The chapter also discusses the *dahi* and other related fermented products manufactured by incorporating starch.

2.1 ELEPHANT FOOT YAM

Elephant foot yam is one of the most nutritious, but underutilized tuberous vegetable crop. It has the appearance of an elephant's foot and thereby has its name. Because of its higher yield potential, culinary properties, medicinal utility and therapeutic values, it is referred to as 'King of Tuber Crops' (Sengupta *et al.* 2008) and also as "Money Spinning Tuber Crop" due to the high mean profits associated with it (Singh *et al.* 2008). It is chiefly valued for its edible tuber and profound medicinal properties (Hanelt and IPK, 2001; Ochse and Van der Brink, 1980).

EFY belongs to the family Araceae (Aroid family) along with taro, giant taro, swamp taro and cocoyam and the family is known for supply of famine foods (Sankaran and Palaniswami, 2008). Its botanical name is *Amorphophallus paeoniifolius* (Dennst.) Nicolson (syn. *Amorphophallus campanulatus* Decne) and in Hindi, it is known as *Zaminkand* and/ or *Jimmikand*. Other vernaculars of EFY are *Arsoghana* (Sanskrit), *Oi* (Bhojpuri), *Suran* (Gujarati), *Kanda* (Telugu), *Chena* (Malyalam), *Karnai-kilangu* (Tamil), *Suvarna gadde* (Kannada), etc. The geographical origin of the crop lies in Asia, South East Asia and Melanesia (Lebot, 2009).

2.1.1 Production

The genus *Amorphophallus* has got more than 200 species. About 19 species have been reported from India and out of these only 4 species (*A. bulbifer*, *A. commutatus*, *A. muelleri* and *A. paeoniifolius*) are being used either as food or medicine. *A. paeoniifolius* (elephant foot yam) is cultivated commercially in states like Andhra Pradesh, West Bengal, Tamil Nadu, Orissa, Bihar, Gujarat, Kerala and Jharkhand. Andhra Pradesh occupies top position

both in area and production of elephant foot yam in India, which is the world leader.

There are no authentic published data on area, production and yield statistics for aroids and yams in India. However attempts to compile area under elephant foot yam in different parts of the country indicated that it is grown in an area of 32,000 ha producing 6.7 lakh tonnes with productivity of 21t ha⁻¹ (CTCRI, 2010).

2.1.2 Botanical description

Elephant foot yam is a robust herbaceous plant, with an erect solitary stem usually 1-2.5 m in height and bearing at the top one or two tripartite leaves, each part of which is deeply dissected into numerous segments. Towards the end of the plant's cycle a large terminal inflorescence is produced, consisting of a short stalk and spathe and a spadix, which emits a malodorous smell, reminiscent of rotten meat due to dimethyl sulphide and dimethyl trisulphide (Kite and Hettterscheid, 1997; Kite *et al.* 2008). The corms are large globose depressed tubers, usually dull-yellow or brownish-yellow in colour, and these produce 5-10 cormels at the end of each growing season. The growth cycle of the corms normally takes about 8-12 months but the tubers are small and unmarketable after only one season and 3-4 seasons are required for an economic crop.

The depressed globose corms often have a diameter of 30 cm or more, and under good cultural conditions can weigh 7-9 kg by the fourth season (Kay and Gooding, 1987).



Fig. RL1. Elephant foot yam

2.1.3 Composition of elephant foot yam

Wide variations are seen in the composition foot of elephant foot yam tuber as reported by different workers. The composition of elephant yam as adapted from Bradbury and Holloway (1988) is reported in Table RL1.

Table RL1. Composition of elephant foot yam

Constituents	(%)	Minerals	(mg/100 g)	Vitamins	(mg/100 g)
Moisture	77.8	Calcium	127	Vitamin A (retinol+ β carotene)	0.15
Energy (kJ/100 g)	324	Phosphorus	67	Thiamine	0.05
Protein	2.24	Magnesium	47	Riboflavin	0.07
Starch	16.6	Sodium	4.1	Nicotinic Acid	0.7
Sugar	0.14	Potassium	622		
Dietary Fibre	1.45	Sulphur	11.8		
Fat	0.06	Iron	0.51		
Ash	1.36	Copper	0.18		
Oxalates	(mg/100 g)	Zinc	1.05		
Total oxalate	288	Manganese	0.31		
Calcium oxalate	382	Aluminium	0.41		
		Boron	0.17		

Chhatopadhyay *et al.* (2010) evaluated nutritional composition of 12 different cultivars of elephant foot yam and noticed a wide variation in the compositional aspects of different cultivars. The dry matter content was found ranging from 17.50 to 24%, starch from 13.93 to 21.53%, sugar from 0.55 to 1.77%, protein from 0.84 to 2.60%, fat from 0.07 to 0.37%. The soluble oxalate content ranged from 6.65 to 18.50 mg/100 g. The minerals were also found to varying in their amount. EFY contains a wide range of phytochemicals including alkaloids, phenols, flavonoids, glycosides, saponins, steroids and tannins (Ramalingam, 2010). The major bioactive constituents present are-

dimethyldisulphide, dimethyltetrasulphide, dimethyltrisulphide and alkaloids (Kite and Hetterschield, 1997; Kite *et al.* 1997). Flavonoids content of EFY is 46.33 mg/ g and 36.88 mg/ g (in terms of Rutin equivalent) and total phenolic content was observed to be 12.67 mg/ g and 6.25 mg/ g (in terms of Catechol equivalent) for methanolic extract and hydro-alcoholic extract respectively (Nataraj *et al.* 2009).

Table RL2. Minerals found in different cultivars of elephant foot yam

Mineral	Range (mg/100 g)
Potassium	230-471
Phosphorus	120-247
Calcium	109-198
Iron	1.97-4.04
Manganese	0.19-0.65
Zinc	0.12-1.92

Corm also contains triacontane, lupeol, betulinic acid, stigmasterol, β -sitosterol and its palmitate, glucose, galactose, rhamnose and xylose (Asolkar *et al.* 1992). Corm shows antiprotease (Prathibha *et al.* 1995), tyrosinase and laccase activity (Paranjpe *et al.* 2003). Das *et al.* (2009) isolated a water-soluble polysaccharide from the aqueous extract of the corm having D-galactose, D-glucose, 4-O-acyl-D-methyl galacturonate, and L-arabinose in a molar ratio 2:1:1:1. This molecule showed splenocyte activation.

2.1.4 Medicinal properties and health benefits

Elephant foot yam shows spasmolytic, antiviral, hypotensive, antiinflammatory, antimycobacterial and antibacterial activity (George and Pandalai, 1949; Gupta and Vishwanathan, 1956; Norton *et al.* 1973; Cox *et al.* 1989). The water extract of *A. paeonifolius* was found to be potent as antioxidant and anticoagulant (Saikia and Konwar, 2011).

2.1.4.1 Antimicrobial activity

A number of compounds i.e. 3, 5-diacetyltambulin, amblyone, salviasperanal isolated from elephant foot yam showed antibacterial activities (Khan *et al.* 2008, 2009). Nataraj *et al.* (2009) found methanolic extract to be highly effective on *Staphylococcus aureus* while *Klebsiella pneumoniae* was

highly sensitive to all the extracts (petroleum ether, hydro-alcoholic (70%), methanol & aqueous). The methanolic and petroleum ether extract also was found to be possessing antifungal activity. Gupta and Viswanathan (1956) observed ether extract of stem to be active against strain *Mycobacterium tuberculosis*.

2.1.4.2 Analgesic activity

Methanolic extracts of tuber showed significant analgesic activity in mice. The extract dose dependently suppressed the frequency of acetic acid-induced writhing in mice (Shilpi *et al.* 2005). Dey *et al.* (2010) found spontaneous dose-dependent increase in analgesic activity on administration of methanolic extract in mice.

2.1.4.3 Hepatoprotective activity

Ethanol extract of tuber have potent hepatoprotective action against carbon tetrachloride induced hepatic damage in rats (Jain *et al.* 2009). Sharstry *et al.* (2010) isolated compound quercetin from *Amorphophallus paeoniifolius* and found that it plays an important role in restoring the disturbed liver function in CCl₄ induced hepatic damage. Also, the tuber extracts have been found to possess immunomodulatory activity (Tripathi *et al.* 2010), anthelmintic activity (Ramalingam *et al.* 2010), cytotoxic activity (Angayarkanni *et al.* 2007; Khan *et al.* 2008) and anti-inflammatory activity (De *et al.* 2010).

2.1.4.4 Medicinal uses

The medicinal uses of elephant foot yam are well recognized in Ayurveda. The corms of elephant foot yam are acrid, astringent, anti-inflammatory, anti-haemorrhoidal, haemostatic, expectorant, carminative, digestive, aperient, appetizer, stomachic, liver tonic, aphrodisiac and rejuvenating (Anonymous, 2010). The corm is used in the folk medicine to cease tumor growth, lung swelling, asthma, vomiting, abdominal pain, piles, hemophilic conditions, skin diseases, obesity, dyspepsia, debility and control intestinal worms (Kirthikar and Basu, 1987; Siraj and Balachandran, 1994; Nadkarni and Nadkarni, 2000; Prajapathi *et al.* 2004). The acrid roots are used medicinally to treat boils (Drury, 1873; Quisumbing, 1978; Jayaweera, 1981; Nadkarni and Nadkarni, 1999). It is a hot carminative in the form of a pickle (Quisumbing, 1978; Nadkarni and Nadkarni, 1999). The corms are caustic, and are employed in anti-rheumatic poultices as rubefacients. The corm relieves the pain of rheumatic swellings when applied

externally (Quisumbing, 1978). It imparts hepatoprotective, antioxidative and uterus stimulating effect (Singh *et al.* 2011; Laderman, 1983). The corm extract is applied externally as an irritant to treat acute rheumatism, administered internally in the treatment of dysentery, diarrhoea, piles, haemorrhoids and in the formulation of indigenous medicines to cure inflammatory conditions and ophthalmia (Drury, 1873; Watt 1889; Quisumbing 1978; Jayaweera 1981; Bala *et al.* 2007; Purwal *et al.* 2011). Because of this effect, in Sanskrit it is as *Arsoghna* or curer of piles (Dey, 1896). Finely crushed *A. campanulatus* corm and *T. indica* leaf is given orally once daily for a fortnight for piles (Kalita and Bora, 2008).

Table RL3. Ayurvedic properties of elephant foot yam

Guna (Quality)	<i>Laghu, Ruksha, Vasada</i>
Rasa (Taste)	<i>Katu, Kasāya</i>
Vipak (Metabolism)	<i>Katu</i>
Virya (Potency)	<i>Usna</i>
Karma (Function)	<i>Kaphara, Dipana, Kushthakara, Rucya</i>

(Ayurvedic Pharmacopeia of India, Govt. of India)

Herb is used in earache, pain, intercostal neuralgia, perpueral fever and swelling of throat (Joshi, 2000). The sap from the petiole is fermented and drunk for treatment of diarrhoea and dysentery (Alister, 1990; Traditional Medicine Database, 2002). The tuber is rubbed on stone with water and given orally to treat pneumonia and asthma (Upadhyay *et al.* 2010). It is used in earache, pain, intercostal neuralgia, perpueral fever and swelling of throat (Joshi, 2000). The decoction of rhizome (5-10 ml), daily is taken orally, to reduce fat in obesity. It is also used in heart diseases (Sharma *et al.* 2001).

2.1.5 Culinary uses of elephant foot yam

Elephant foot yam is highly esteemed for the wholesomeness and nourishing quality of its roots. It is cooked in the manner of the yam and is also used for pickling. It is boiled like potatoes and eaten with mustard; or it is cooked in curries, or it is cut into slices, boiled with tamarind leaves, and made into pickles; it is also cooked in syrup and made into preserve. It can be cooked with salt, chilly, tamarind and turmeric powder and is used as curry (Yesodharan and Sujana, 2007). Various delicious dishes of *Zimikand* are prepared such as curry is made with fresh tuber pieces along with curd/buttermilk and spices. Stem and

tubers are cut into pieces, sundried and used in preparation of delicious curry during off season is the common practice in the state. Typical food item of *Zimikand* is *badi*, a type of preparation made by stem pieces with pulses, spices and then sundried and eaten as deep frying or cooked with other vegetables (Singh *et al.* 2008). Powdered yam is encapsulated with pulp of seeded banana, and consumed for controlling stomach disorders and piles.

Elephant foot yam can be used to produce pickle, *chawanpras*, preserved candy, beverage, jam and dehydrated fruits, which can be helpful in setting processing industries (Kumar *et al.* 2004). Value addition to the corms like preparation of French fries, papads etc. is attempted in small quantities (Murthy *et al.* 2008). It is also utilized in making sweets, mouth fresher and brewing powder similar to tea (Prabhu, 2008). Its utilization through value added products like fried yam balls, yam flour, yam flakes chips, souce, pickles and baked yam is suggested by various agencies. In Assam, farmers consume a dish made of elephant foot yam in the month of *Bhadoh*, which they perceive to be strength giving (Borah *et al.* 2008). Various value added products like pickle, gulabjamun, *kheer*, cutlet etc. from elephant foot yam have been prepared and standardized by Acharya *et al.* (2005).

2.2 ACRIDITY PROBLEM IN ELEPHANT FOOT YAM

Acridity is the most obvious and unpleasant phytochemical quality found in Araceae (Aroid) family. The corms and leaves of most cultivars of the edible aroids are acrid. This means that if eaten raw they cause swelling of the lips, mouth and throat. The sensation of acridity is experienced at its worst when raw or undercooked pieces of corm or leaf are placed in the mouth. It is experienced as a severe itching, stinging or burning sensation in the mouth and throat, followed by swelling—or as a less severe irritation or itching of external skin, on hands and arms. Osiogun *et al.* (1974) observed the effects of acridity sensation of highly acrid cultivar of taro on human subjects. ‘Stinging’ effects were felt on the lips and tongue within moments of chewing the sample. Saliva carried the ‘stinging’ sensation to the throat. The tympanic membrane of the ear also seemed affected and hearing was somewhat blocked. Subjects also felt slight headache. The stinging effect lasted about 25 minutes and hearing impairment about 45 minutes.

2.2.1 Calcium oxalate as agent of acidity

Calcium oxalate crystals occur in different forms throughout the Plant Kingdom. Oxalate occurs in plant tissue in form of crystals, either as soluble salt of sodium, potassium, magnesium or insoluble salt of calcium. These crystals are either monohydrated or dehydrated. These crystals perform various functions, including herbivory deterrence (Hudgins *et al.* 2003), calcium regulation (Franceschi, 1989; Volk *et al.* 2002), heavy metal tolerance (Franceschi and Nakata 2005), ion balance, detoxification, structural strength, and insect repulsion (Lane, 1994; Horner and Wagner, 1995). Plants produce a variety of calcium oxalate crystal shapes and sizes. Most crystals can be classified into one of five categories, based on their morphology: crystal sand, raphide, druse, styloid, and prismatic (Franceschi and Horner, 1980; Prychid and Rudall, 1999; Franceschi and Nakata, 2005). Usually, the morphology of a crystal, as well as its spatial distribution, is conserved within specific taxa. Two distinct types of crystal idioblasts (cells which differ from neighbouring plant tissues and contain non-living substances) occurring in the *Amorphophallus* species observed are: (1) cells containing grooved raphide crystals, and (2) cells that contain a single large or several smaller multi-faceted druses.

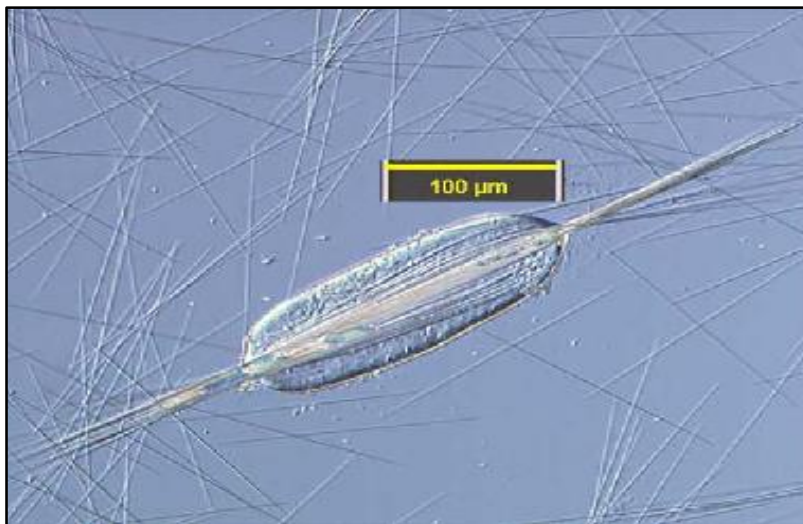
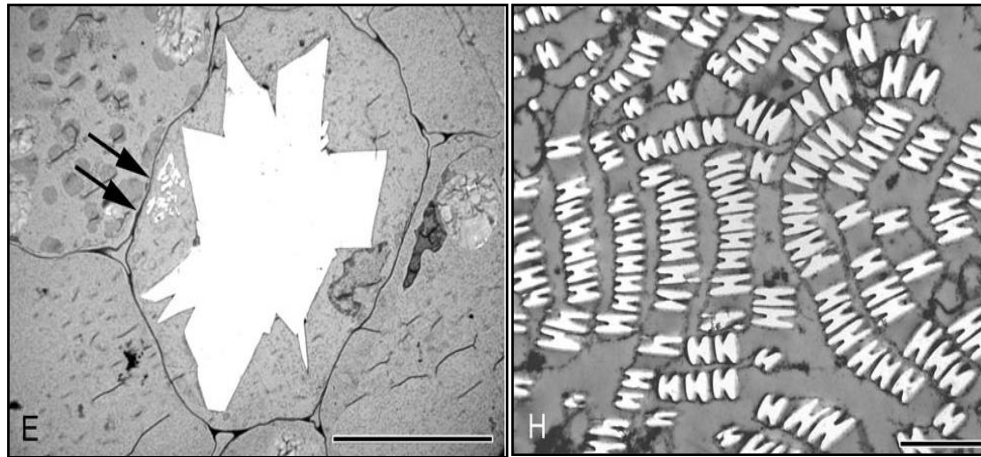


Fig. RL2. Raphide Idioblast

Each of these two specialized cells produces only one crystal type. Raphides are bundles of needle-like crystals that represent the most common crystal type in monocots while druses (cluster crystals) are roughly spherical aggregates of crystals that occur in only a few early-divergent monocot families, but are common in eudicots and early-divergent angiosperms.



Mature druse, filling cell. Crystal deposition in another part of vacuole

Mature raphide crystals showing H shaped cross section

Scale bar: 20 μm

Scale bar: 2 μm

Fig. RL3. Druse and raphide present in plant cell (Prychid *et al.* 2008)

Calcium oxalate crystals are thought to be causing itching sensation. Crystals of calcium oxalate are deposited in plant tissues (Englberger *et al.* 2003). When in sufficient quantity, calcium oxalate crystals cause mechanical abrasion of the mucous membranes and causes irritation and burning sensation in the mouth and throat. The intensity of irritation has been found to differ widely among different cultivars. Large variation has been reported in the content of calcium oxalate in acrid and non-acrid cultivars. Highly acrid cultivars showed calcium oxalate in the range of 660-850 mg/100 g, while non-acrid cultivars had value ranging from 120-140 mg/ 100 g (Sundaresan, 2005). Raphides in aroids are not always acrid, and the degree of acidity in these plants is not always correlated with the abundance of raphides, or the amount of calcium oxalate present. Osiogou *et al.* (1974) found a positive correlation between the abundance of raphides and irritant effects, but also found evidence for the existence of a volatile irritant. The acidity is believed to be due to a combination of calcium oxalate crystals (Bradbury and Holloway, 1988; Saikia and Borah, 1994) and a chemical irritant, which is believed to be either a diglucoside of 3,4-dihydroxybenzaldehyde (Saha and Hussain, 1983; Suzuki, 1980), an unidentified proteinase (Bradbury and Hammer, 1990; Fochtman *et al.* 1969), or a hormone or sapotoxin (Walter and Khanna, 1972).

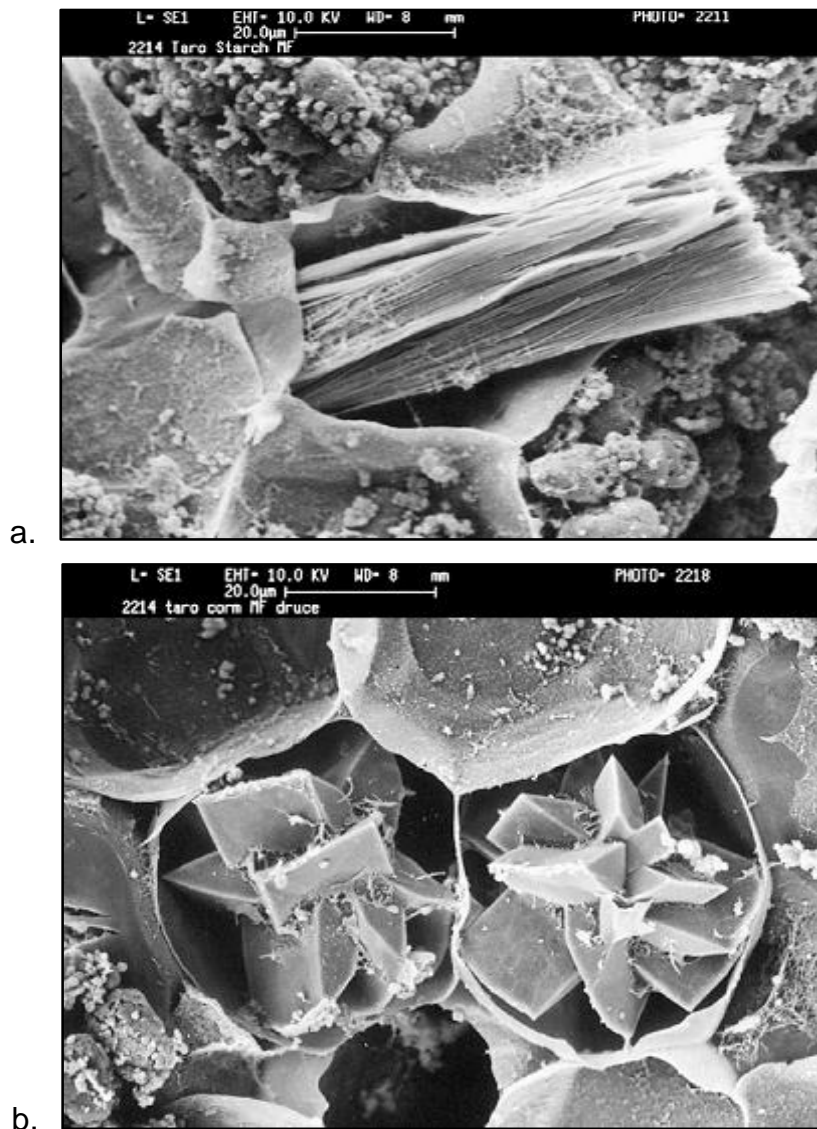


Fig. RL4. Brake surface of fresh taro samples showing druses (A) and raphide (B) idioblasts projecting into intercellular space in corm (Aboubakar *et al.* 2009)

Paull *et al.* (1999) observed that the acidity in Araceae species is not apparently due to calcium oxalate raphides, and raphides apparently function to carry the acidity factor- a 26 kDa protein (cysteine protease). Bradbury and Nixon (1998) coined the term Nature's poisoned spear for the action of raphide/irritant complex on the soft skin tissue that results in acidity.

2.2.2 Solutions to the acidity and/or oxalate problem

Acridity and/or oxalate are the critical factors that have averted the usage of elephant foot yam as a food crop. Removal of acidity would not only be advantageous for human consumption of corms and leaves but also for animal food, because plants of family Araceae are wasted because of the acidity

problem. The problem of acidity and/or oxalate can be effaced by improving the indigenous cultivars available in the germplasm through breeding techniques by generating variability or by use of various processing methods.

2.2.2.1 Non-acrid varieties

The development of non-acrid varieties under the aegis of All India Coordinated Research Project on Tuber Crops (other than potato) started in 1976. The non-irritant variety was selected in West Godavari district and released as *Gajendra* for commercial cultivation in 1989. From then onwards, various non-acrid varieties having high yield and good cooking qualities have been released by AICRP research centres. Some of released cultivars are *Sree Padma*, *Sree Athira*, *Bidan Kusum* and NDA-9.

Table RL4. Nutrient composition of *Gajendra* cultivar of elephant foot yam

Major Constituent	(%)	Minerals	(mg/100 g)
Dry Matter	23.00	K	344
Starch	17.00	P	152
Sugar	0.83	Ca	172
Crude Protein	1.87	Fe	3.37
Fat	0.37	Mn	0.65
Energy	349.30 kJ/100 g	Zn	1.47
Soluble Oxalate	17.15 mg/100 g		

(Chattopadhyay *et al.* 2010)

2.2.2.2 Traditional Processing Methods

Various traditional processing systems are followed in different regions for elimination of acidity. Pre-soaking, boiling, additions of ingredients like tamarind, curd, buttermilk etc. in cooking medium are some of the common traditional methods which are normally employed to elude the acidity. Furtado (1940) noted claims that adding acidic ingredients or sodium bicarbonate can help to reduce acidity during cooking; and also, milk, thick syrup of sour lime or tamarind, or solid tamarind with or without salt, can help alleviate the ill effects of acidity. May (1984) recommended lime juice as an antidote for acidity, while Hollyer *et al.* (1997) suggested a wash with baking soda. In northern Australia, Aborigines use a series of cooking, pounding and leaching steps to render wild-type taro edible (free from acidity). Tu (1981) used aqueous alkali to remove acrid principles from

the aroid corms. Huang and Hollyer (Patent No.5464646 dated Nov. 7, 1995) invented a method of removing acidity substances from *Araceae* tubers without cooking by soaking it in alkali water for specific time interval.

The process is as follows:

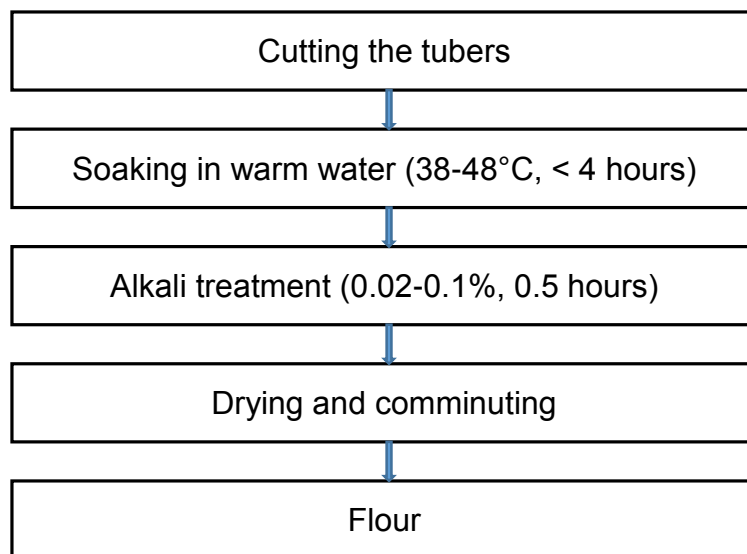


Fig. RL5 Flow chart depicting preparation acid free Araceae flour

Acridity was found to be inversely related to soaking temperature as well as the concentration of alkali used. Soaking period of 2-4 hours was found to be sufficient for reduction of acidity. In North-Eastern states of India, the elephant foot yam is boiled in bamboo shoot ash water for removing acidity. The bamboo shoot acts as alkali and repeated boiling and drying helps in breaking down the calcium oxalate crystals (Sankaran *et al.* 2008). Simpson *et al.* (2009) showed that the addition of cows' milk or coconut milk are equally effective at reducing the soluble oxalate content of the final baked mix, even though the coconut milk contained a low level of calcium compared to cows' milk.

2.2.2.3 Bacterial degradation and Fermentation

Oxalate-degrading bacteria have been isolated from various habitats such as aquatic, terrestrial, thermophilic and gastrointestinal (Sahin, 2003).

Oxalobacter formigenes a symbiotic, gram negative, obligate anaerobe bacterium found in the GI tracts of vertebrates, including humans plays an important role in regulating oxalate homeostasis in humans (Allison *et al.* 1986). The bacterium metabolizes oxalate into formate and carbon dioxide (Allison *et al.* 1985). This bacteria not only degrades free oxalate entering the intestinal lumen, but also creates a trans-epithelial gradient, favouring oxalate secretion and preventing

absorption of oxalic acid in the lower intestinal region (Hatch and Freel, 2005). The key role of *O. formigenes* in the human oxalate homeostasis makes the bacterium an important tool in the effort of developing new strategies for the treatment of oxalate related maladies. Further, LAB (lactic acid bacteria) component of the intestinal microflora of dogs and cats are known to degrade oxalate in vitro. Weese *et al.* (2004) reported that canine and feline faecal samples degraded oxalates. Ren *et al.* (2011) also observed oxalate degrading capacity in lactic acid bacteria isolates from dogs. On similar lines, Campieri *et al.* (2001) observed that administration of high doses of combination of LAB resulted in reduction of oxaluria in human subjects. Biochemical activities during the process of fermentation and sprouting have been reported to be utile in removing oxalate and/or acidity. Carpenter and Steinke (1983) found that anaerobic fermentation of leaves in an underground pit for several weeks removed the acidity and it was termed as neutralization or destruction of acidity factor. Antai and Obong (1992) observed, marked decrease in oxalate content of *Ipomoea manni* (a starch tuber) upon fermentation. Oxalic acid decreased by 37% during souring of poi (a cooked taro paste) at 20°C (Huang *et al.* 1994). Aremu *et al.* (1995) found a decrease in the oxalate content of cocoa beans during process of fermentation which is essential for the development of strong flavour. Meduoa *et al.* (2007) described that metabolic activities due to sprouting caused decrease in the oxalate content of trifoliate yam. Ensiling of chopped taro leaves caused 54% reduction in oxalate content of chopped taro leaves (Hang and Preston, 2010). Oseni and Akindahunsi (2011) reported fermentation by *Rhizopus oryzae* to be causing about 45.5% reduction in oxalate content of the seed of *Jatropha curcas* L.

2.2.2.4 Cooking Processes

Boiling, steaming, baking, drying and roasting are generally resorted as methods for removing the oxalate and/or acidity problem. Reduction of oxalate and/or acidity factor during cooking implies thermal lability of these components. Banks (1963) reported that acidity of taro tubers and leaves can be removed by cooking. Osisiogu *et al.* (1974) found reduction in irritant effect of cocoyam after boiling for 15 min. and complete disappearance after 1 h boiling. Moy *et al.* (1979) reported that prolonged cooking (boiling or baking) removes the acidity of taro tubers. Boiling removes the aforementioned components by thermal degradation and leaching phenomenon. Cleveland and Soleri (1991) reported

that boiling/ steaming of vegetables and then rinsing and discarding the cook water reduced the oxalate content. Wanasundera and Ravindran (1992) reported 40-50% loss of total oxalates in yam tubers (*Dioscorea alata* and *D. esculenta*) on boiling whilst reduction on steaming was only 20-25%. Iwuoha and Kalu (1995) noticed that boiling caused oxalate reduction of 82.1% in INB variety of cocoyam. The decrease was 61.9% due to roasting in EUH variety (165°C for 40 min) and 43.3% in CC1 variety due to steeping (room temperature, 24 h).

Bakr and Gawish (1997) observed that up to 40% of oxalate in spinach can be reduced by boiling. Savage *et al.* (2000) also showed that boiling caused a significant loss of soluble oxalates in some New Zealand foods. Boiling significantly decreased the oxalate concentration in the whole tuber of Oca (Albihn and Savage, 2001). Similarly, Judprasong *et al.* (2006) noticed that cooking boiling caused significant reduction ($p \leq 0.05$) in total and soluble oxalate content and the reduction ranged from 18-76% and 30-83%, respectively, in different vegetables. Quinteros *et al.* (2003) reported that all the cooking procedures reduced the soluble oxalate contents in pulses, but microwave and industrial procedures were found more effective than the traditional domestic cooking. Chai and Liebman (2005) found that boiling vegetables decreased total oxalate content 30-87%, primarily by loss of soluble oxalate and, in spinach and carrots the decrease in total oxalate corresponded to the amount of oxalate found in the cooking water. Boiling may cause considerable skin rupture and facilitate the leakage of soluble oxalate into cooking water. Bhandari and Kawabatta (2006) processed 4 different cultivars of Wild yam tubers of Nepal by boiling and pressure cooking and reported reduction of 31-53% and 16-26%, respectively. Catherwood *et al.* (2007) reported 64-77% reduction in total oxalate level of 4 different cultivar of Japanese taro by boiling. Cooking for 4-5 min in boiling water and then wilting in basket for 15 min resulted in 53% reduction of oxalate content of chopped taro leaves (Hang and Preston, 2010). Boiling caused reduction of 22.4-70.3% reduction in total oxalate, 15.6-76.9% reduction in soluble oxalate content in various vegetables (Akhtar, 2010). Blanching a much shorter duration heat treatment has also been reported to decrease the oxalic acid content in spinach (Kim *et al.* 1993; Park *et al.* 1994). Udosen and Ukpanah (1993) found that blanching significantly reduced the oxalate content and the reduction was 34% in dill leaves and 30% in dill plant.

Unlike, moist heat treatments (boiling, steaming, blanching) which cause reduction in oxalate content, the dry heat treatments (baking, roasting, drying) are not much successful. Baking was found to increase the concentration of soluble oxalates in the cooked tissue (Albihn and Savage, 2001; Wanasundera and Ravindran, 1992; Savage *et al.* 2000; Albihn and Savage, 2001). Baking potatoes (Chai and Liebman, 2005) or roasting peanuts (Judprasong *et al.* 2006) or sesame seeds (Toma *et al.* 1979) does not affect oxalate content. In contrast, Sefa-Dedeh and Agyir-Sackey, (2004) showed that drying methods, similar to baking, decreased the concentration of oxalate in taro species to about 50%, due to reported oxalate degradation. Sundaresan and Nambisan (2008) reported drum drying to be effective in 50% reduction of calcium oxalate content in taro and cocoyam. The reduction was about 25% in *Amorphophallus* and it was acid free.

2.3 FERMENTED DAIRY FOODS

Fermented milk products have a long and culturally diverse history. These are those foods which have been subjected to the action of micro-organisms or enzymes so that desirable biochemical changes cause significant modification to the food (Campbell-Platt, 1987). Their exact origins are difficult to establish; but they probably date back more than 10,000 years to a time when populations changed from food gatherers to food producers. For generations, fermented milk products have provided world populations who lacked refrigeration with a safe, convenient and nutritious food. Fermented foods are healthy and used to soothe stomach disorders or digestive upsets. The dietetic value of Indian fermented milk products is due to its content of vitamins, proteins, minerals, carbohydrates and various therapeutic activities.

2.3.1 Dahi

Dahi is a one of the milk products of major importance in the Indian sub-continent. It is yoghurt like product made in India and neighbouring countries. It is the most important fermented milk product used in India from times immemorial. It is a lactic acid fermented product. *Dahi* is a traditional Indian fermented product prepared by fermentation of milk by lactic acid bacteria. *Dahi* differs from yogurt in its use of mixed starters of mesophilic *lactococci*. It is consumed directly either as sweetened or as salted and spiced form. It is also consumed with food such as rice or chhapati. *Dahi* is a very nourishing food. It is a good source of essential

vitamins and minerals. It has high medicinal values in Ayurveda and finds a very prominent position in Indian culture, food habits and religious ethos. As per FSSR 2011, *dahi* or curd means the product obtained from pasteurised or boiled milk by souring, natural or otherwise, by a harmless lactic acid or other bacterial culture. *Dahi* may contain added cane sugar. *Dahi* shall have the same minimum percentage of milk fat and milk solids-not fat as the milk from which it is prepared. Where *dahi* or curd is sold or offered for sale without any indication of class of milk, the standards prescribed for *dahi* prepared from buffalo milk shall apply. Milk solids may also be used in preparation of this product. The desirable qualities in *dahi* offered for sale for direct consumption have been given below:

Table RL5. Desirable quality attributes of *dahi*

Qualities	Requirements
Colour	Yellowish creamy-white for cow and creamy-white for buffalo milk; free from browning.
Appearance	Smooth and glossy surface; creamy layer on top (with whole milk product), free from extraneous matter.
Flavour	Mild pleasant smell, clean acid taste, free from off-flavour.
Body	Soft and firm, free from gas-holes and whey-pockets.
Acidity (%LA)	0.75-0.85

Table RL6. Indian standards requirements for *dahi*

Characteristics	Requirements
Acidity , as lactic acid (% by mass)	0.60-0.80
Yeast and mold count g ⁻¹ (max)	100
Coliform count g ⁻¹ (max)	10
Phosphatase test	Negative

Dahi is a highly nutritious product containing all the nutrients present in milk, which is further improved under the influence of metabolic activity of starter cultures during fermentation. *Dahi* is reported to have better nutritive value than milk from which it is prepared. Though there is no increase in fat or protein content of milk during fermentation, due to fermentation the digestibility of *dahi* is

more than that of milk. The dietetic value of *dahi* is due to its content of vitamins, proteins, minerals, carbohydrates and various therapeutic activities. In addition, the changes in milk constituents that occur during lactic acid fermentation influence the nutritional and physiologic value of the finished *dahi* product.

2.3.2 Lassi

Lassi is a popular indigenous fermented milk beverage, which is usually prepared by mixing *dahi* and water in required proportions. It is refreshing, delicious and nutritious and also possesses thirst quenching property, by virtue of which it is quite popular among all age groups (Mathur, 1991). It is a ready to serve beverage, which is widely consumed in summers in chilled form. It is a white to creamy white, viscous liquid with a sweetish aroma and mild to medium acidic taste. Salted and spiced *lassi* can be made by adding salt and spices like ginger, coriander and mint in the form of a paste in place of sugar and desired consistency is attained with the addition of cold water (Tiwari, 1997). Good quality *lassi* should have a creamy consistency, smooth texture, glossy sheen, white colour with yellowish tinge and a sweetish rich aroma with mild to high acidic taste. Salted and spiced *lassi* can be made by adding salt and spices like ginger, coriander and mint in the form of a paste in place of sugar and the desired consistency is attained with the addition of cold water (Sabikhi, 2006). Salted variety of *lassi* is preferred in our Southern parts, whereas in North it is relished as sweet. *Chhas* or *matha* a desi buttermilk, which is the by-product obtained when churning curdled whole milk with crude indigenous devices for the production of desi butter (*makkhan*) is also called *lassi* (De, 1980). *Lassi* like beverage made from yoghurt, salt and water is popular in the areas of the Middle East including Iran and Lebanon as *doogh* and in Turkey, it additionally contains lemon and served in hot summer days. It is prepared from milk having 1.5-4.5% fat after making set curd, followed by vigorous stirring to break the curd and addition of sugar syrup plus optional flavour.

The composition of *lassi* depends upon the initial composition of milk, the degree of concentration of milk solids and the quantity of sugar added. The approximate composition of *lassi* is as follows: milk fat 1.5-3.8%; milk TS 9.0%; sugar 13-20%; sodium dihydrogen phosphate 0.5%; low methoxy pectin 0.5% and acidity 0.7% lactic acid minimum. It has a limited shelf life of about 1-2 days

at ambient temperature and 2-3 weeks at refrigerated temperature (Ramanna and Tiwari, 1999).

2.3.3 Vegetables in fermented dairy products

Very less work has been done on the processes for making vegetables fortified fermented dairy products. Vegetables, due to their high nutritive value offer a chance to be incorporated into fermented dairy products. These can be added in fermented dairy products in various forms i.e. flour, powder, puree etc.

Yoghurt like fermented product manufactured by addition of sweet potato puree was having increased firmness, flavor and enhanced nutritive value. The fermentation time was 0.75-1.75 h longer than control. Product having 16% sweet potato was found to be most acceptable (Collins *et al.* 1991). Sweet potato curd manufactured from β carotene rich sweet potato puree and cow milk with curd starter (*Lactobacillus bulgaricus*, *Streptococcus thermophilus*, *Streptococcus diacetylactis*, etc.) @ 2% and incubated at $30\pm 2^\circ\text{C}$ for 18 h had firm body and improved nutritional value. *Dahi* with 12-16% puree was most preferred by consumer (Mohapatra *et al.* 2007). Spillman and Farr (1983) investigated the consumer acceptance of yoghurt containing vegetables. Yoghurt made with cucumber and onions were very well liked. Yoghurt containing blend of cucumber, spice and celery was found to be very much liked by the 45% of geriatric panellists. Some of the vegetable blends were found to be popular with university student, children and geriatric citizens.

2.3.4 Starch in fermented dairy products

The development of a three-dimensional protein network is essential for yoghurt or *dahi*. The network formed is affected by use of stabilizers or other hydrocolloids. Elastic gel structure of *dahi* forms at pH -5.6, due to changes in the micelle structure because of colloidal calcium phosphate (CCP) solubilisation. Further reduction in pH causes a more complex and extensive interconnection of casein particles leading to formation of a continuous protein network and thus, maintaining structure of yoghurt (Steventon *et al.* 1990; Shoemaker *et al.* 1992; Lee and Lucey, 2004; Martin *et al.*, 2005). Textural properties of yoghurt like viscosity (Marshall and Rawson, 1999), smoothness, thickness (Jaworska *et al.* 2005), and structural resistance to stress (Skriver *et al.* 1999) are important attributes based on protein content, heat treatment of the mix (Harwalkar and Kalab, 1986; Lee and Lucey, 2010), and the presence or absence of milk fats,

bacterial exo-polysaccharides, and stabilizers (Modler and Kalab, 1983; Schellhaass and Morris, 1985; Teggatz and Morris, 1990). It has been reported that the viscosity of yoghurt appears to be more influential than flavor (van Vliet *et al.* 1997; Jaworska *et al.* 2005) and found to be affected by the addition of the stabilizers (Fizman *et al.* 1999; Lucey, 2002; Jimoh and Kolapo, 2007).

2.3.4.1 Effect of starch addition on characteristics of fermented dairy products

Stabilizers have the ability to form a network of linkages between themselves and the milk constituents because of the hydrogen or carboxyl radicals present in their structure (Tamime and Robinson, 1999). The negative sides got attached at the interface and water bound in basic mix due to the presence of stabilizers. Level of hydration improved by the attachment of water to milk constituents (proteins), forming a network that reduces the free movement of water (Ingenpass, 1980). Starch and other hydrocolloids (carrageenan, guar gum, locust bean gum, xanthan gum, carboxymethylcellulose) are used to combat variations in viscosity and/or expulsion of serum. A typical stabilizer system for yoghurt may include starch, gelatin and pectin. Modified starches can be used up to <0.8% level while starches can be used up to 2% level (Lucey, 2004). Ispghol (*Plantago ovata*), a psyllium seed husk is also used as stabilizer in dairy foods. It is a very cheap gelling agent (Atici *et al.*, 2008) which after coming in contact of water forms a sticky substance (Gupta, 1982) due to swelling and expansion of mucilaginous polysaccharide. It is also used as hydrocolloid as it improves the water retention property (Rubis, 1990) of different food products.

Stabilizers yield gel networks, when incorporated in dairy products leading to firm texture, and consequently problem of syneresis in yoghurt is reduced. The selection of a specific type of stabilizer for any specific type of product depends upon factors such as effect or mode of action of the stabilizer and functional properties and optimum concentration of the stabilizers to be used (Tasneem *et al.* 2014). Keogh and O'Kennedy (1988) reported that addition of starch did not affect the dynamic consistency index but, high level of fat increased the dynamic consistency index for starch. The increase was more in starch added yoghurt rather than for gelatin or xanthan/locust bean gum added yoghurt. Fat increased the consistency index by the largest amount (10.49 Pas) in the starch trials. The yoghurts made with starch had the highest shear consistency than was for gelatin or xanthan/locust bean gum mixture. They also noticed decrease in syneresis,

but to an insignificant level after starch addition. Jogdand *et al.* (1991) noticed higher level of starch (1.5%) to be unsuitable from consistency viewpoint of *dahi*. Its effect on the flavour and overall acceptability was insignificant. They advocated use of 1% starch to overcome the wheying off problem and improve the quality of *dahi*. Yoghurt made from modified tapioca starch (MTS) showed relatively open and loose structure and exhibited higher firmness than full fat yoghurt ($p \leq 0.05$), despite more open and loose structure, due to the carbohydrate molecule of modified tapioca starch which strongly bind and orient water increasing the viscosity of the continuous phase (Sandoval-Castilla *et al.* 2004). Williams *et al.* (2003, 2004) reported effects of modified corn starch addition in yoghurt. The addition of starch at 0.5-1.0% level increased the whey drainage but higher levels (2.0%) caused a reduction in whey drainage. Addition of modified waxy maize starch had little effect on the fermentation time but it caused a perception of reduced smoothness. Also, graininess was found to reduce with added starch when fermentation times were increased by lowering the fermentation temperature. Starch addition resulted in reduction of gelation time and an increase in gelation pH.

Oh *et al.* (2007) found that the addition of potato starch resulted in higher storage modulus in the acid gels. The addition of starch increased the storage modulus values of acid milk gels and the magnitude of increase was dependent on the level of starch added to the milk. Addition of potato starch increased the firmness of acid gels. The increasing level of potato starch showed a linear increase in the storage modulus. No effect was observed on the breaking strain while breaking stress showed complex effect. Microscopy showed that the starch granules were embedded in the dominant protein network. Jimoh and Kolapo (2007) noticed the effect of different stabilizer viz., gelatin, corn starch and cassava starch at 0.5% level of addition on acceptability of soy-yoghurt. Gelatin stabilized yoghurt was rated best followed by cassava starch stabilized soy-yoghurt. They suggested that cassava starch could be utilized as stabilizer in soy-yoghurt production.

Amaya-Llano *et al.* (2008) used acid thinned jicama and maize starches as fat substitute in stirred yoghurt. Stirred yogurt formulated with hydrolyzed starches showed different properties of syneresis index according to the starch type and hydrolysis conditions. The addition of hydrolysed jicama starch (2.03

g/100 g) as a fat substitute in the preparation of stirred yogurt had good functional and sensorial properties. Mehmood *et al.* (2008) used various additives like CMC, guar gum, corn starch and gelatin alone or in combination to improve the quality of yoghurt. The incorporation of additives influenced the pH, acidity, total solids and acetaldehyde content of yoghurts. The addition of corn starch in yoghurt was found to increase total solid, free fatty acid and acetaldehyde content of the yoghurt. Alakali *et al.* (2008) noticed effect of various stabilizers (gelatin, carboxyl methyl cellulose (CMC) and corn starch) at different levels (0, 0.5, 0.75 and 1.0%) on thermized yoghurt. Addition of corn starch produced the yoghurt having most desirable flavour and taste, which was significantly different from gelatin added yoghurt. The CMC based yoghurt was found to be having best mouth-feel characteristic which were not significantly different from corn containing yoghurt. Yoghurt produced by addition of 0.75% CMC has the most overall sensory characteristics followed by those stabilized with 0.75 and 0.5% corn starch.

Alting *et al.* (2009) added amylo-maltase treated starch to low fat yoghurt. Addition of amylo-maltase treated starch raised the creaminess perception of low-fat yoghurt (1.5%) to that of full-fat yoghurt (5%). The ATS domains are enclosed in or bound to the protein network and did not appear in the serum phase after extensive centrifugation. ATS domains resemble the microstructural behaviour of fat particles. Starch caused a decrease of the concentration of aroma compounds in the head space, due to the molecular interaction between its helical chains and aroma compounds (Decourcellea, 2004). Radi *et al.* (2009) manufactured low fat (1.6%) and non-fat yoghurts from acid treated wheat starch and acid treated cross linked wheat starch at concentration of 1.6% and 3.2%. Acid treated cross link starch (1.6%) was more firm than control, followed by acid treated cross link starch (3.2%). Addition of modified starch decreased the water release of the yoghurts significantly. As the concentration of starch increased the syneresis decreased. They concluded that good quality non-fat and low fat yoghurts can be made by utilizing acid treated cross linked starch. Zare *et al.* (2011) supplemented the yoghurt with lentil flour (1-3% w/v) and noticed changes in its sensory and physical properties. Yogurt with 3% lentil flour showed higher storage (G') and loss (G'') moduli in comparison with non-supplemented control yogurt. 1–2% lentil flour supplemented yogurt showed comparable sensory

properties in comparison with the control yoghurt sample. Syneresis in 1–2% lentil flour supplemented yogurts was significantly higher than all other samples; however, greater lentil supplementation (3%) resulted in the lowest syneresis.

Cui *et al.* (2014) investigated the effect of cross-linked acetylated starch on the set yoghurt system (flowability, viscoelasticity, zeta potential, conductivity and microstructure). The results indicated that the stability, elastic modulus and viscous modulus of set yogurt increased with the concentration of cross-linked acetylated starch. The yogurt added with cross-linked acetylated starch, exhibited shear-thinning behaviour and belonged to yield pseudoplastic fluid. The cross linked starch strengthened the casein network. Starch adsorbs onto the surface of the casein micelle and prevents flocculation of the casein micelles owing to electrostatic adhesion, steric stabilization and osmotic effect. Lobato-Calleros *et al.* (2014) prepared reduced fat stirred yoghurt by addition of three different kinds of starches i.e. native maize starch, chemically modified maize starch and tapioca starch. They reported control yoghurt to be exhibiting lower apparent viscosity-shear rate profiles and dynamic viscoelastic moduli, but higher syneresis than the reduced-fat yogurts. The tapioca starch added yoghurt displayed least syneresis value. The addition of native or chemically modified starches from different origin to reduced-fat yogurts contributed to the formation of more stable dispersed acidified milk gelled systems. They concluded that chemically modified starch can induce positive impact in syneresis, flow and viscoelastic properties as compared with a full-fat yogurt by contributing to the formation of more stable milk gels.

CHAPTER – 3

Materials and Methods

3. MATERIALS AND METHODS

This chapter includes the materials and methods employed to carry out the present investigation. The chapter also deals with various instrumental and analytical techniques adopted for various kind of analysis (physico-chemical and statistical), carried at different stages of research work. The statistical analysis carried out during the present study has also been included in this section. The details have been discussed below.

3.1 MATERIALS

3.1.1 Elephant foot yam

Two cultivars of elephant foot yam were utilized in present study viz. local variety and *Gajendra* variety. Local variety of elephant foot yam was purchased from wholesale vegetable market, Karnal, Haryana and *Gajendra* cultivar of elephant foot yam was purchased from Navsari Agriculture University, Navsari, Gujarat.

The elephant foot yam purchased from the market was cleaned and washed thoroughly with water to remove any external soil or dust and then it was kept for some time to dry the surface water. The corm was peeled using stainless steel knife. After peeling it was diced into (~2 cm³) pieces using stainless steel knife. The cubes were immediately dipped in 0.1% potassium meta-bisulphite solution for 5 min to prevent the enzymatic browning. The cubes were stored overnight at 5°C. The cubes were then blanched in boiling water for 10 min and cooled immediately. The cubes were allowed to surface dry for 10 minutes at 25°C, after wiping extra moisture with blotting paper. The cubes were then packed in nylon pouches and stored in freezer (-20°C) till further study.

3.1.2 Buffalo milk

Fresh buffalo whole milk was procured from Experimental Dairy of the National Dairy Research Institute, Karnal.

The milk obtained was standardized to defined level of fat and solid non-fat content as per the experimental plan using whole milk, skim milk and skim milk powder.

3.1.3 Skim milk powder

Skim milk powder was procured from M/s Modern Dairies Ltd., Karnal.

3.1.4 Psyllium husk

The psyllium husk (*Isabgol- Plantago ovate*) (Sat Isabgol, Sidhpur, Gujarat) was obtained from local market. The psyllium husk obtained was dried in oven at 105°C for 30 min. The dried husk was then ground for 3 min using grinder (Maxie food processor, Inalsa appliances, Gautam Budh Nagar). The powder, thus obtained was packed in nylon pouch and stored till further study.

3.1.5 Packaging material

Then nylon pouches used for storing elephant foot yam and other material were obtained from Hitkari Industries Ltd., Parwanoo, Himachal Pradesh.

The polystyrene cups used during consumer analysis of *dahi* were obtained from Experimental Dairy Plant of the Institute.

3.1.6 Starter culture

Dahi culture (NCDC-144), comprising strains of *Streptococcus thermophilus* and *Lactobacillus delbreuckii* subsp. *bulgaricus* was obtained from National Collection of Dairy Cultures (NCDC), Dairy Microbiology Division, National Dairy Research Institute, Karnal. Starter cultures obtained from the NCDC (NCDC-144) were maintained in sterilized skim milk. The fresh skim milk (100 ml) was taken into 250 ml conical flasks and plugged with non-absorbent cotton plugs. The flasks were transferred in autoclave and sterilized at 15 psi pressure for 15 min. The culture was propagated by inoculating sterilized skim milk with active starter @ 2% using laminar air flow chamber. The flasks were incubated at 37°C for 12 h and stored at 5°C. The propagation of the culture was done at alternate days to maintain culture activity.

3.1.7 Salt, spices and sugar

Commercially available iodized table salt (Tata Chemicals Ltd., Mumbai) and spices (MDH Pvt. Ltd., Kirti Nagar, Delhi) used during the preparation of salted lassi were procured from local market.

Cane sugar (sucrose) used in preparation of sweet *lassi* was obtained from the Experimental Dairy Plant of the Institute.

3.1.8 Flavour

The different flavours (Bush Boake Allen (India) Limited, Chennai) utilized during preparation of sweet flavoured lassi were procured from local market.

3.1.9 Chemicals

All the chemicals used in the preparation of different reagents were of analytical grade (AR) and were procured from standard companies. The reagents required for analysis were freshly prepared adopting standard procedures.

3.2 METHODOLOGY

3.2.1 Pre-soaking treatment study of elephant foot yam

Pre-soaking is a common detoxification technique used for plant foods for making them edible for humans. It helps in removal of toxic compounds by leaching. The pre-soaking treatment study of elephant foot yam was conducted in 3 stages viz. elephant foot yam storage, pre-soaking treatment of the elephant foot yam and analysis.

The frozen elephant foot yam cubes were thawed overnight in refrigerator at 5°C. The thawed yam cubes were soaked in different pre-soaking medium (EFY: water- 1:6) for different time period viz. 60 min, 90 min and 120 min. Pre-soaking mediums used were-

- 0.01, 0.05 and 0.1% sodium hydroxide solution
- 2, 6 and 10% salt (sodium chloride) solution
- 2, 6 and 10% salt solution acidulated to pH 3.5 (using citric acid solution)

After pre-soaking, the soak water was drained and cubes were washed in running tap water. The cubes were then cooked in boiling water for 30 min. The cubes were taken out and immediately cooled in chilled water. Cooled yam cubes were then stored at 5°C for further analysis (oxalate content and acidity score).

The pre-soaked and cooked elephant foot yam cubes were made into paste using mixer (Maxie food processor, Inalsa appliances, Gautam Budh Nagar, Uttar Pradesh, India), dispersed in milk and subjected to sensory (acidity) analysis.

3.2.2 Alkaline pre-soaking using response surface methodology

A Response Surface Methodology (RSM) experiment was designed incorporating the soaking time and temperature ranging from 1-3 h and 40-50°C, respectively as the process variables (factors). A total of 13 different combinations were worked out using Central Composite Rotatable Design (CCRD) to investigate the effect of aforementioned factors on the response

variables viz. oxalate content (total and soluble), sensory acidity score, hunter colour parameters, whiteness index and total solids in soak water.

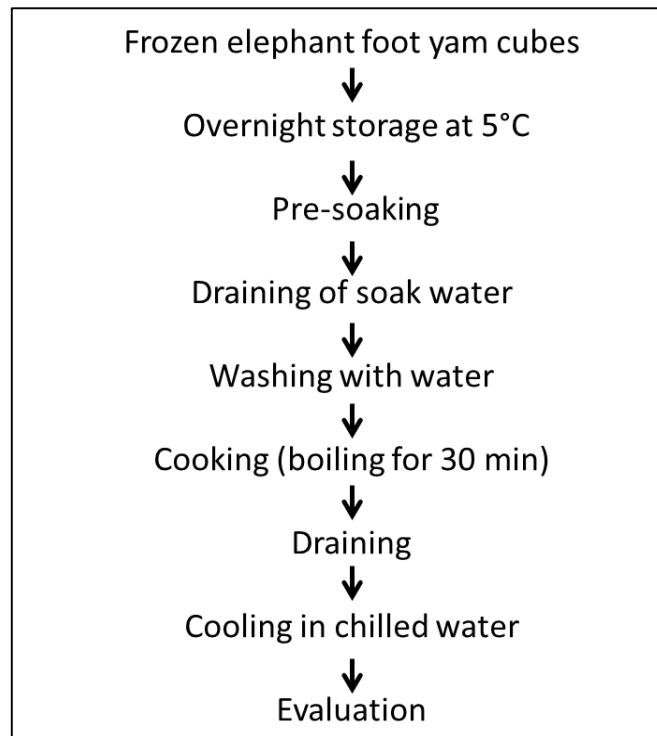


Fig. MM1. Flow chart for preparation of pre-soaked cooked elephant foot yam

Table MM1 represents coded and actual values of the process variables in the RSM experiment, while Table MM2 gives the experimental design matrix. The design matrix consisted of 5 centre points, 4 axial points and 4 factorial points. The response variables were related with the coded factors using either a response surface quadratic model:

$$Y = b_0 + b_1A + b_2B + b_{11}A^2 + b_{22}B^2 + b_{12}AB + \varepsilon$$

or, a response surface linear model:

$$Y = b_0 + b_1A + b_2B + \varepsilon$$

The coefficients of the polynomial were represented by b_0 (constant term), b_1 , b_2 (linear terms), b_{11} , b_{22} (quadratic terms), b_{12} (interactive terms) and ε (random error).

The pre-soaking treatment study of elephant foot yam (var. *Gajendra*) was conducted into 3 stages viz. elephant foot yam storage, pre-soaking treatment of the elephant foot yam and analysis.

Table MM1. Coded and actual values of the process variables in the RSM experiment

Independent Variable	Levels				
	Axial point	Factorial point	Centre co-ordinate	Factorial point	Axial point
	-1.413	-1	0	+1	+1.413
A: Temperature (°C)	37.929	40	45	50	52.071
B: Time (h)	0.586	1	2	3	3.414

Table MM2. Design matrix for two independent variables i.e. time and temperature for RSM experiment using CCRD design

Run	Process Variables	
	Temperature (°C)	Time (h)
1	50	1
2	50	3
3	45	0.59
4	37.93	2
5	45	2
6	40	1
7	52.07	2
8	45	2
9	40	3
10	45	2
11	45	2
12	45	3.41
13	45	2

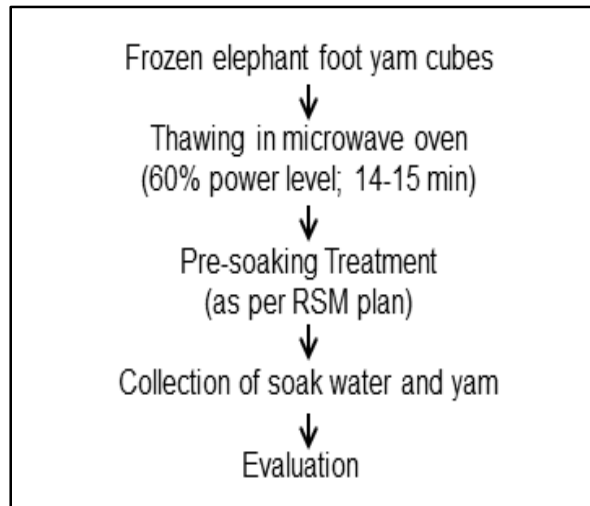


Fig. MM2. Flow chart for preparation of alkali pre-soaked elephant foot yam

The frozen elephant foot yam cubes were thawed in a microwave oven (60% power level for 14-15 min). The thawed yam cubes were then soaked in sodium hydroxide solution (0.1%) (Merck, Mumbai, India) for varying periods at different temperatures (as given by CCRD of RSM), with intermittent stirring (5 min) for repositioning of yam cubes. At the end of the pre-soaking period, the cubes were allowed to drain for a few seconds and the stored in beakers at 5°C till further analysis. The soak water was collected separately for analysis. The pre-soaked elephant foot yam cubes were made into paste using Maxie food processor (Inalsa appliances, Gautam Budh Nagar, India) and subjected to analysis. The yam paste for oxalate analysis was stored at -20°C until use.

To validate the adverse effects of alkali pre-soaking on the sensory status of EFY, the yam was subjected to two different sets of alkali pre-soaking conditions, which represented two extremes (60 min at 40°C and 180 min at 50°C) of the process variables along with respective controls. The treated yam was subjected to sensory evaluation on a semi-structured scale (0-nil to 4-extreme) for different sensory parameters viz., darkening (colour), softness, acidity and blandness of taste (Annexure-3).

3.2.3 Pre-soaking and cooking of elephant foot yam under alkaline conditions produced by NaHCO₃

Similar to sec 3.2.1, here alkaline pre-soak-cook treatment was tried to mitigate the acidity problem; but instead of plain water cooking, yam cubes were cooked in sodium bicarbonate solution of different concentrations. The soaking and cooking was conducted as per plan. The three treatments investigated were:

soaking in 0.1% NaOH (60 min) with cooking in 0.25% NaHCO₃ (30 min); soaking in 0.5 % NaHCO₃ (60 min) with cooking in 0.25% NaHCO₃ (30 min); and soaking in 0.5% NaHCO₃ (overnight) with cooking in 0.5% NaHCO₃ (30 min) along with control (soaking in plain water (60 min) followed by cooking for 30 min). The treated yam thus obtained was analyzed for appearance, Hunter color values and hand-sensed acidity (Annexure 1).

3.2.4 Cooking of elephant foot yam in boiling water

The frozen elephant foot yam cubes were thawed. The thawed yam cubes were dipped in boiling water (EFY: water- 1:6) for different time period i.e. 10, 20, 30 and 40 min. After boiling, yam cubes were removed from the soak water and soak water was collected separately. Yam cubes were spread on blotting paper under air for cooling and then made into paste using mixer and stored at -20°C for further analysis. The process is depicted in Fig. MM3. The analysis was carried out with regard to the effect of the period of cooking in boiling water on oxalate content (via hydrothermal degradation) and other characteristics viz. whiteness index, phenolic content and DPPH activity. Yam cubes were also subjected to sensory evaluation for different sensory attributes i.e. sensory colour, acidity and softness of EFY (Annexure 4). The soak water was examined for the loss of yam solids.

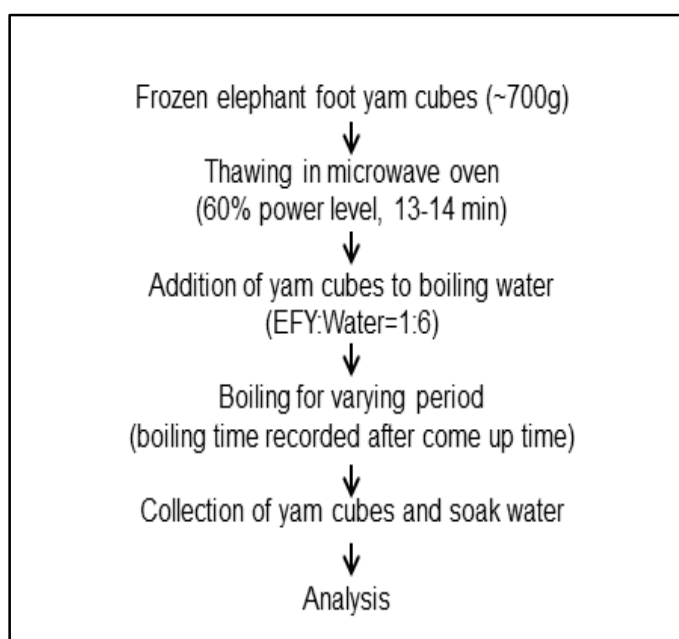


Fig. MM3. Flow chart for preparation of cooked elephant foot yam

3.2.5 Drum Drying of Cooked Elephant Foot Yam

For drum drying operation, local cultivar was used instead of *Gajendra* variety. The EFY purchased from the local market was diced (2 cm³) using a knife, which were subsequently dipped in 0.1% K₂S₂O₅ to prevent undesirable browning. The cubes were then cooked in boiling water for 30 minutes.

After draining, the cooked yam cubes were twice passed through cheese grinder. The paste so obtained was made into slurry by using either water or skim milk. It was further ground by use of pulverizer (Lakshmi Industries, Ludhiana). After that it was passed through fryma grinder (ML-150, Fryma Maschinen, Switzerland) and later the slurry was homogenized at 2000 psi (single stage) using homogenizer (H-102, GOMA Engineering Pvt. Ltd., Mumbai). The slurry, obtained was dried using twin drum dryer (P210, NTN Corporation Ltd., Canada) at different total solids level by using either water or skim milk for satisfactory drying. The quantity of slurry used for drying was 90-100 kg. The drums were supplied with steam (4-5 kg/ cm²) and rotated at constant speed of 20 rpm.

3.2.6 Spray Drying of Cooked Elephant Foot Yam

For the spray drying of elephant foot yam, methodology aforementioned in sec 3.2.5 was followed till the homogenization step. Post that, spray drying was performed with following set of conditions using nozzle-atomizer, co-current spray dryer (SSP Ltd., Faridabad).

- Feed temperature- 65°C
- Inlet Temperature-185°C
- Outlet Temperature- 80°C
- Air Pressure- 5 kg/ cm²

3.2.7 Tray drying of cooked elephant foot yam

To obtain cooked elephant yam powder, the EFY was subjected to hot air drying. After boiling the EFY cubes for 10 min, the EFY cubes were converted to homogeneous paste in a mixer (Maxie food processor, Inalsa appliances, Gautam Budh Nagar, Uttar Pradesh, India). The EFY paste (~510 g) so obtained was evenly spread on steel trays. The trays loaded with homogeneous paste were dried at different temperatures (50°C, 60°C, 70°C) individually using tray dryer (Accolab Instruments and Equipments, Ambala Cantt, India). The dryer was run for 60 min to obtain steady conditions before placing product in the dryer. The paste was dried till it acquired a brittle consistency.

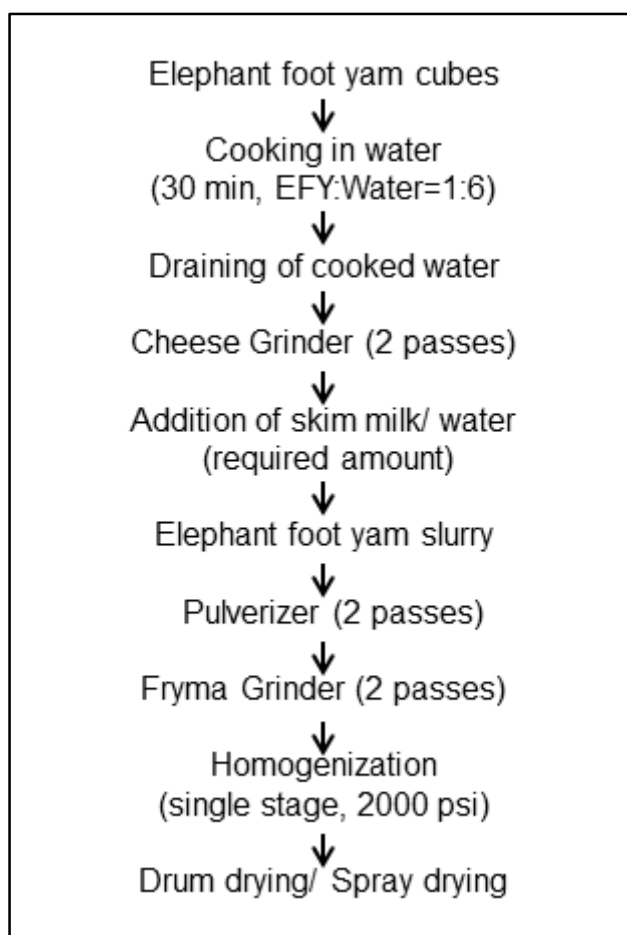


Fig. MM4. Process flow chart for drum/ spray drying of elephant foot yam

After completion of drying process, trays were taken out from the dryer and kept at room temperature for 30 min. The dried paste was scrapped from the trays and packed in nylon pouches. Milling of the product to fine particle size was done using colloid mill (1093 Cyclotec, Foss Tecator AB, Sweden). Pre-grinding of the dried product was done in kitchen mixture (Maxie food processor, Inalsa appliances, Noida, India) before milling to make it easily pass through the colloid mill. The powder thus obtained was sieved through 60 mesh size standard sieve with particle size around 250 μ .

The yam powders thus obtained were analyzed for physical properties (whiteness index, browning index, bulk density, true density and porosity), physical functional properties (water absorption index, water solubility index, oil absorption index and pasting properties) and phyto-chemical content (soluble oxalate, total oxalate, total phenolic content, DPPH activity and ABTS activity). The sensory attributes (flavor and mouthfeel) of yam milk dispersion were

evaluated on a 10 cm semi-structured linear (intensity-rating) scale (0-100) (Annexure- 5).

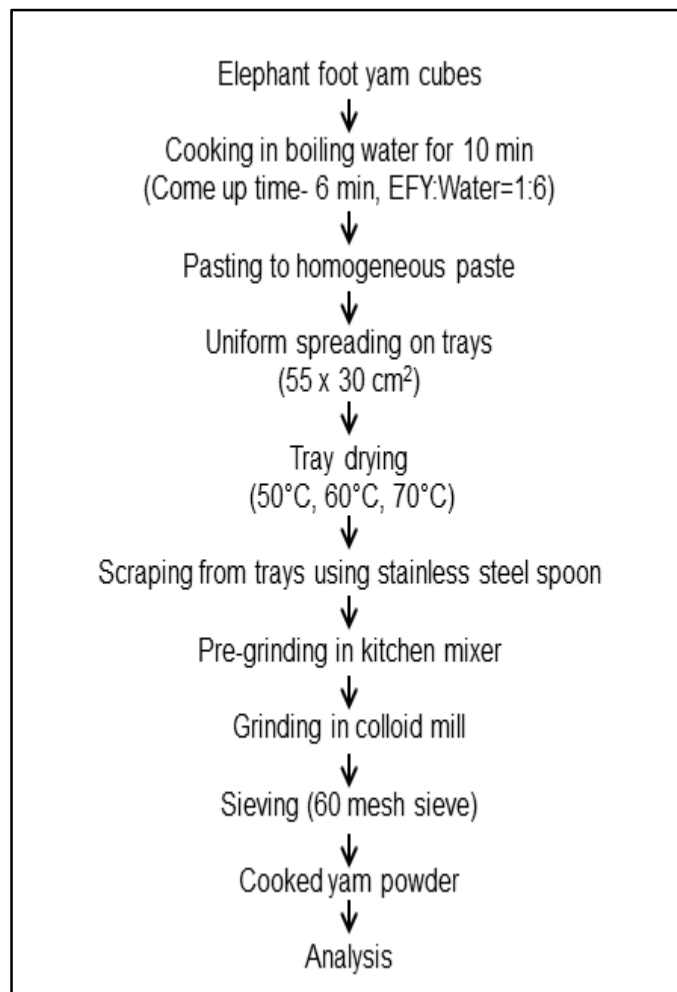


Fig. MM5. Process flow chart for preparation of cooked-yam powder

3.2.8 Dahi blended with elephant foot yam

An RSM (Response Surface Methodology) experiment was designed to examine the effects of the EFY solids (EFYS), psyllium solids (PSY) and milk fat (MF), together with interactions among them so that an optimum combination can be worked out. The experiment was designed incorporating EFYS, PSY and MF ranging from 0.5-2.0%, 0.1-0.3% and 1.5-4.5%, respectively as process variables.

A total of 17 different combinations were worked out using Box Behnken Design (BBD) to investigate the effect of aforementioned factors on the response variables viz. sensory attributes (appearance, firmness, flavor, consistency and mouthfeel), whiteness index, water holding capacity and instrumental texture parameters (firmness, work of adhesion, work of shear and stickiness).

Table MM3. represents coded and actual values of the process variables in the RSM experiment along with the experimental design matrix. The design matrix consisted of 5 centre points and 12 factorial points.

Dahi was prepared from buffalo milk with different levels of MF, EFYS and PSY (as per RSM plan). Prior to addition of EFYS and PSY, milk was standardized to 9% SNF level. After addition of yam and psyllium solids, the milk was mixed well with hand blender (DX-505, Lee Handy, Leema Industries, India) and kept for 30 minutes for hydration. The milk was then pasteurized at 80°C. The mix so obtained, was homogenized at 2000 psi (1500 psi + 500 psi- double stage) in a homogenizer (H-102, GOMA Engineering Pvt. Ltd., Mumbai). After homogenization, the dispersion was cooled to 45°C.

The milk was then inoculated with NCDC-144 culture @ 2% and mixed thoroughly with hand blender. The mix was then poured into cups and/ or beakers and kept at 42±1°C for incubation in a BOD incubator (SANYO Electric Biomedical Co., Ltd., Japan) for 5-6 hours. The *dahi* so obtained was immediately transferred to refrigerator maintained at 5±1°C. The *dahi* samples were then evaluated for their various physico-chemical and sensory attributes.

Fig. MM6 represents the process flow chart for preparation of yam blended *dahi*.

3.2.9 Sweetened and flavoured *lassi* blended with elephant foot yam

Lassi was prepared from optimized *dahi* as described by Maurya (2012) with slight modifications. The level of sugar was fixed at 15% and level of dilution was varied (water: *dahi*= 1:1, 0.8:1, 0.6:1 and 0.5:1). The sugar was dissolved in equal quantity of hot water (pasteurized) and filtered through clean and dry muslin cloth. The sugar syrup thus obtained was heated to 90°C and cooled to room temperature.

The *dahi* obtained was manually broken using stainless steel ladle, mixed with the sugar syrup and blended thoroughly using a hand blender (DX-505, Lee Handy, Leema Industries, India) for 5 minutes. The various flavours (mango, pineapple, rose and vanilla) were then added @ 1 ml/ kg. The freshly prepared *lassi* was then stored under refrigerated condition (5 ± 1°C) and evaluated.

Table MM3. Box-Behnken RSM design for three independent process variables

Run No.	Standard order	Block	Actual level of variables			Coded level of variables		
			EFYS (%)	PSY (%)	MF (%)	A: EFYS	B: PSY	C: MF
1	17	1	1.25	0.2	3.0	0	0	0
2	1	1	0.50	0.1	3.0	-1	-1	0
3	3	1	0.50	0.3	3.0	-1	+1	0
4	8	1	2.00	0.2	4.5	+1	0	+1
5	13	1	1.25	0.2	3.0	0	0	0
6	15	1	1.25	0.2	3.0	0	0	0
7	4	1	2.00	0.3	3.0	+1	+1	0
8	12	1	1.25	0.3	4.5	0	+1	+1
9	11	1	1.25	0.1	4.5	0	-1	+1
10	2	1	2.00	0.1	3.0	+1	-1	0
11	16	1	1.25	0.2	3.0	0	0	0
12	7	1	0.50	0.2	4.5	-1	0	+1
13	6	1	2.00	0.2	1.5	+1	0	-1
14	14	1	1.25	0.2	3.0	0	0	0
15	5	1	0.50	0.2	1.5	-1	0	-1
16	10	1	1.25	0.3	1.5	0	+1	-1
17	9	1	1.25	0.1	1.5	0	-1	-1

*EFYS-elephant foot yam solids, PSY-psyllium, MF-milk fat

3.2.10 Salted and spiced *lassi* blended with elephant foot yam

The salted variant of *lassi* was prepared in accordance to Hussain (2008) with slight modifications. The firm curd obtained after incubation was broken with help of stainless steel ladle and pasteurized water containing salt (0.8%), cumin (0.25%) and black pepper (0.05%) was added to it. The dilution level (amount of water added to achieve desired consistency) was varied (Water: *Dahi*= 0.9:1.0, 0.8:1.0 and 0.7:1.0).

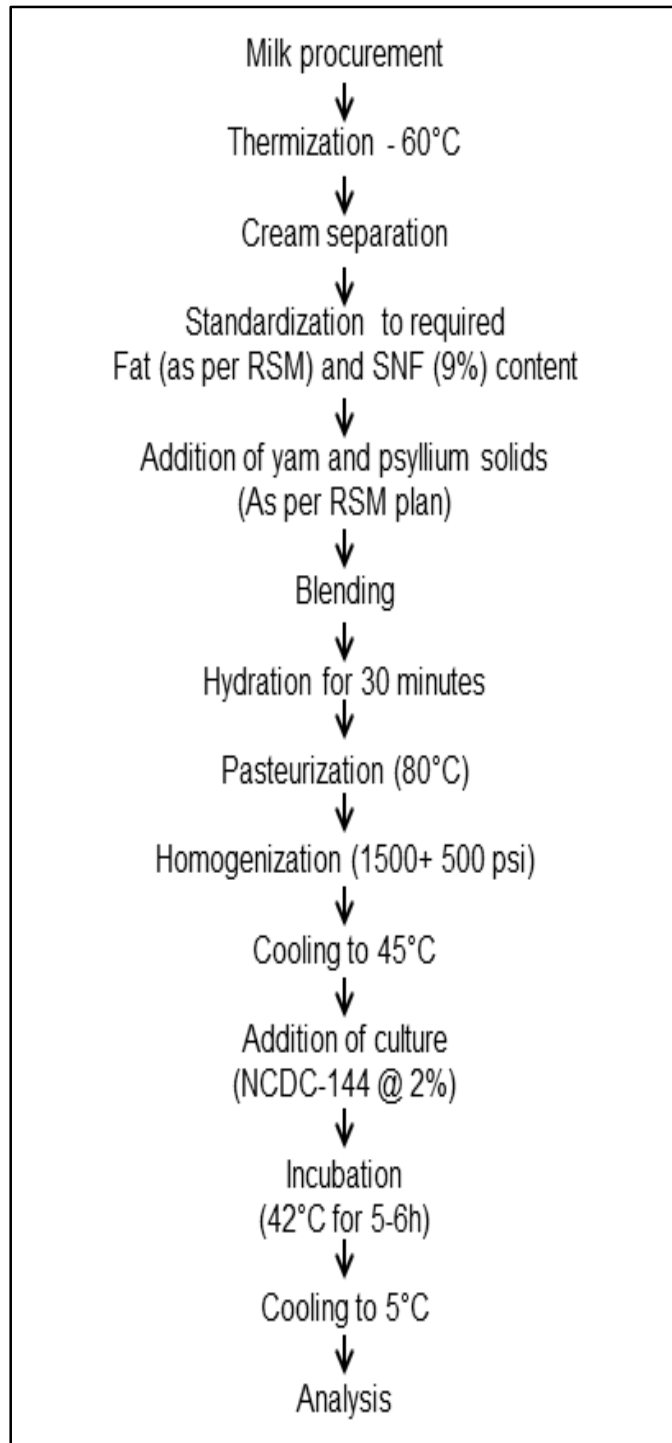


Fig. MM6. Process flow chart for the preparation of yam *dahi*

The mix was blended thoroughly using a hand blender (DX-505, Lee Handy, Leema Industries, India) for 5 min. The freshly prepared lassi was then stored under refrigerated condition ($5\pm 1^\circ\text{C}$) and evaluated.

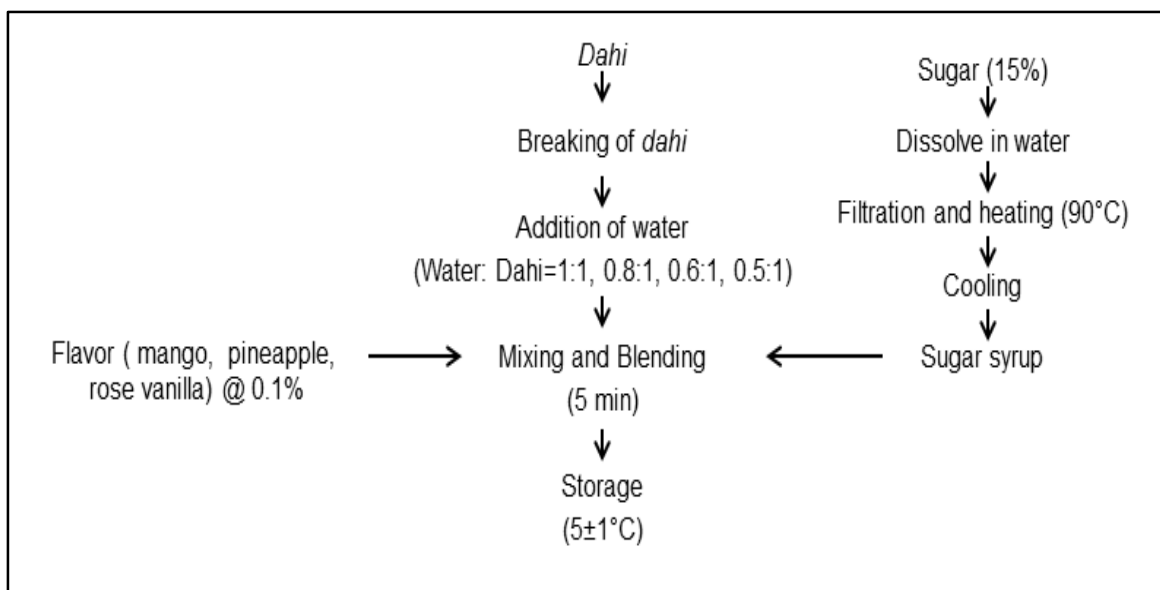


Fig. MM7. Process flow chart for preparation of sweetened flavoured *lassi*

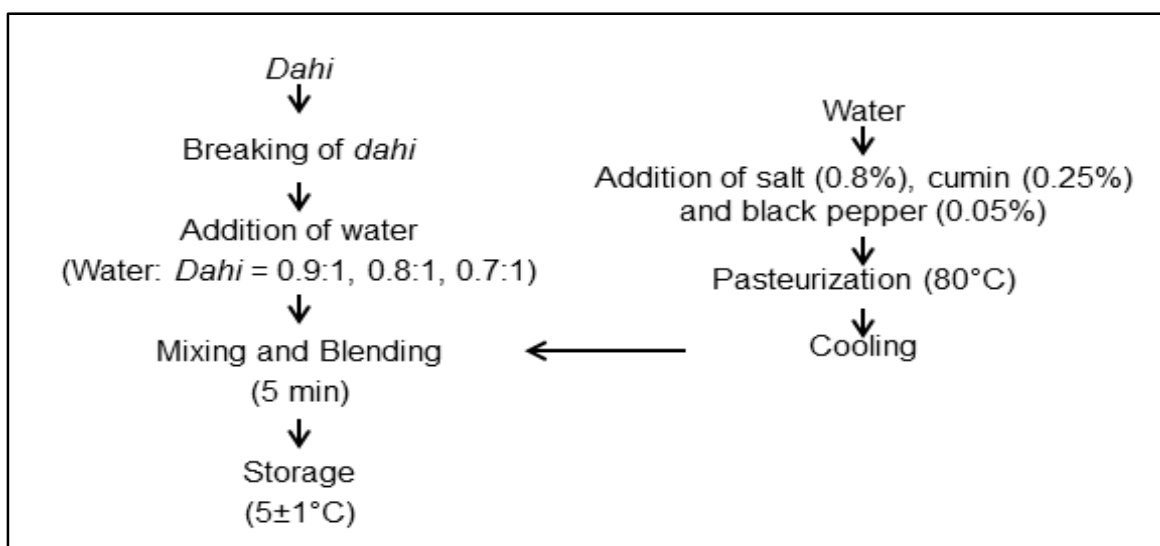


Fig. MM8. Process flow chart for preparation of salted and spiced *lassi*

3.2.11 Storage of *dahi* blended with elephant foot yam

To know about the changes occurring during the storage, *dahi* containing yam solids was packed in glass beakers covered with aluminium foil and polypropylene cups with lids, and stored at refrigeration temperature ($6 \pm 1^\circ\text{C}$) for 12 days. The stored product was examined at 3-days intervals for probable changes in its physical, sensory and textural properties.

3.3 ANALYTICAL PROCEDURES

3.3.1 Physical Parameters

3.3.1.1 Instrumental colour analysis (Hunter L*, a* and b* values)

Hunter L*, a*, b* values of sample were measured employing spectrophotometer, Colorflex® Model No. 45/0 (Hunter lab, Reston, Virginia, USA) using D65 illuminant and 10° standard observer. Before the test, the instrument was calibrated with standard black glass and white tile as specified by the manufacturer.



Fig. MM9. Hunter Colorflex 45/0 measurement system

The light source was dual beam xenon flash lamp. Data are received from the software in terms of L* ranging from 0 (black) to 100 (white); a*, positive 'a' is red and negative 'a' is green, and b*, positive 'b' is yellow and negative 'b' is blue as per the Hunter colour system.

Whiteness index (WI) was calculated according to Cardoso *et al.* (2007) as under:

$$WI = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}}$$

where, L, a, and b are Hunter color values.

3.3.1.2 Sedimentation

The centrifugation method was used to determine sedimentation in yam-milk mix. 10 g of sample was weighed into 15 ml plastic centrifuge tube. The mix was centrifuged at 1200 rpm for 3 min (SIGMA Laborzentrifugen, 2-16 PK, Osterode am Harz, Germany). The supernatant was decanted and pellet was weighed. Sedimentation was reported as per gram of sample.

3.3.1.3 pH

10 g of sample was weighed and dispersed in 100 ml of water (Direct-Q 3UV, Millipore, France). The pH of the solution was measured using pH meter (pH Tutor, Eutech Instruments, Malaysia). Before the experiment, pH meter was calibrated using standard buffer solutions supplied by the manufacturer.

3.3.1.4 Bulk density, true density and porosity

The volume displacement method described by Hsu *et al.* (2003) was used to determine particle density (PD), bulk density (BD), and porosity of yam powders. A portion of yam powder (W_2) was added to a pre-weighed volumetric cylinder (W_1) and the volume was read as V_1 . After the same volume (V_1) of displacement fluid (isobutyl alcohol: phthalic acid diethyl ester=1:1) was added to the cylinder, the total volume of the powder plus solvent in the cylinder was taken as V_2 . TD, BD, and porosity were calculated according following equations.

$$PD = \frac{(W_2 - W_1)}{(V_2 - V_1)} ; BD = \frac{(W_2 - W_1)}{V_1} ; Porosity = 1 - \frac{BD}{TD}$$

3.3.1.5 Browning Index

Browning index of the elephant foot yam powder samples was determined by extracting the powder (4.0 g) with 80% ethanol (20.0 ml) at 30 ± 1 °C for 30 min, with occasional stirring at 5 min intervals, under darkness. The clear supernatant was obtained through centrifugation at 4000 rpm for 20 min (SIGMA Laborzentrifugen, 2-16 PK, Osterode am Harz, Germany). The absorbance was immediately measured at 420 nm against the distilled water blank in a spectrophotometer (Genesys 10 UV, Thermospectronic, USA).

3.3.1.6 Water absorption index and water solubility index

The water absorption index (WAI) was determined according to the method of Anderson *et al.* (1970). Distilled water (5 mL) was added to ground sample (0.2 g) in a weighed 15 mL glass centrifuge tube. The tube was agitated on a vortex mixer for 2 min and then centrifuged for 20 min at 700 g. The supernatant liquid was poured into a tarred evaporating dish. The remaining gel was weighed and the WAI was calculated as:

$$WAI = \frac{m_g}{m_s}$$

where m_g is the weight of the hydrated gel (g) and m_s is the weight of sample (g). The water solubility index (WSI) was determined from the amount of dry solids recovered by evaporating the supernatant from the water absorption test as:

$$WSI = \frac{m_{ds}}{m_s} * 100$$

where m_{ds} is the weight of dry solids from the supernatant (g) after evaporation and m_s is the weight of the sample (g).

3.3.1.7 Oil absorption index

Oil absorption index (OAI) was determined according to the method of Liadakis *et al.* (1993). Refined corn oil (about 2 g) was added to sample (0.5 g) in a 15 mL centrifuge tube. The tube was agitated on a vortex mixer for 1 min, left for 30 min and centrifuge for 20 min at 700 g. The free oil was weighed. OAI was calculated as:

$$OAI = \frac{m_{abs}}{m_s}$$

where m_{abs} is the mass of oil absorbed and m_s is the mass of the sample.

3.3.1.8 Pasting properties

Pasting properties of EFY powders were measured on a Rapid Visco Analyser (RVA-4), using the RVA General Pasting Method (Newport Scientific Pvt. Ltd., Warriewood, Australia). A sample of 2.5 g of powder (5% moisture basis) was transferred into a canister and approximately 25 ± 0.1 ml distilled water was added (corrected to compensate for 5% moisture basis). The slurry was heated to 50°C and stirred at 960 rpm for 10 sec for thorough dispersion, followed by constant stirring at 160 rpm. The slurry was held at 50°C for up to 1 min, and then heated to 95°C in 3 min 42 sec and held at 95°C for 2 min 30 sec, and cooled to 50°C in 3 min 48 sec and holding at 50°C for 2 min. Each analysis took 13 min to complete.

The pasting temperature (the temperature where viscosity first increases by at least 25 cP over 20 s period), peak time (the time at which peak viscosity occurred), peak viscosity (the maximum hot paste viscosity), holding strength or trough viscosity (the trough at the minimum hot paste viscosity), final viscosity (the viscosity at the end of test after cooling to 50°C and holding at this temperature), breakdown (peak viscosity - holding strength or trough viscosity) and setback (final viscosity- holding strength) were calculated from the pasting

curve, using ThermoLine version 2.2 software Newport Scientific Pvt. Ltd. (Warriewood, Australia).



Fig. MM10. Rapid Visco Amylograph (RVA-4) measurement system with waterbath

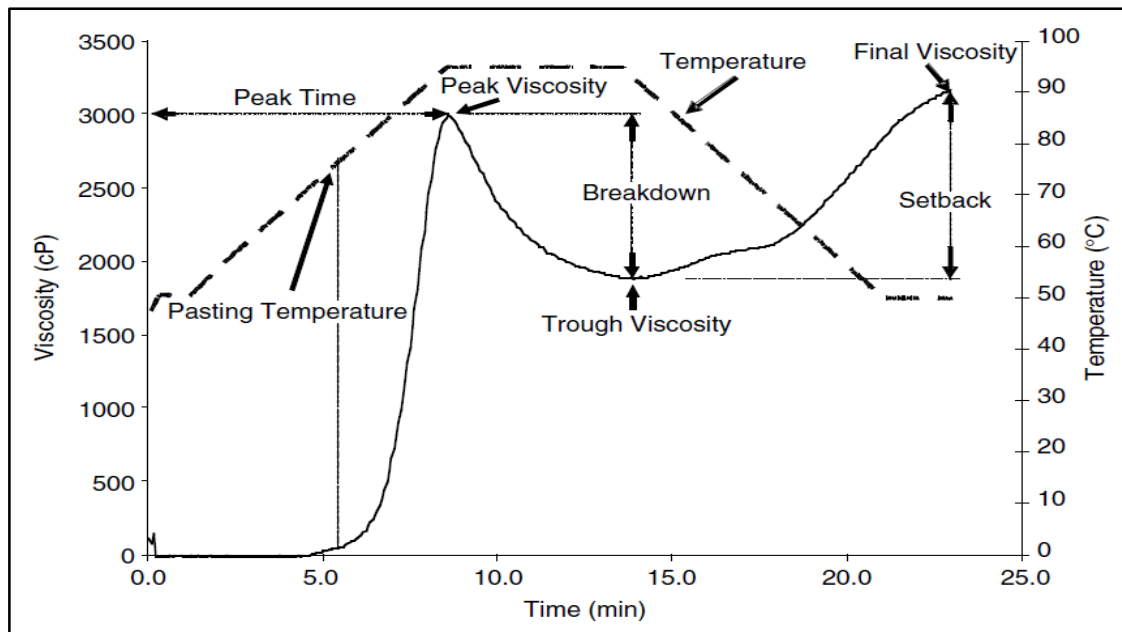


Fig. MM 11. Typical RVA pasting profile showing the significant points during heating and cooling of flour/ starch sample

3.3.1.9 Water holding capacity

Water holding capacity (WHC) was measured by the centrifugation method described by Abbasi *et al.* (2009) with slight modifications. A 30 g of sample was centrifuged at 3000 rpm for 15 min at 5°C. The supernatant was removed, and the pellet weight was recorded. WHC was calculated as:

$$WHC (\%) = \frac{Pellet\ weight}{Weight\ of\ sample} \times 100$$

3.3.1.10 Syneresis

Syneresis was measured by the centrifugation method described by Amatayakul *et al.* (2006). A cup of set *dahi* removed from the refrigerator was stirred 20 times clockwise and anticlockwise with a glass rod. Approximately 30 g of the stirred *dahi* was transferred into a 50 ml polypropylene conical centrifuge tube (Tarsons Products Pvt. Ltd., India) using a 5 ml pipette and left at 5°C for 2 h for stabilization. The stirred samples were then centrifuged at 3000 rpm for 15 min at 10 °C. The separated whey was weighed. The syneresis was calculated as:

$$Syneresis (\%) = \frac{Weight\ of\ whey}{Weight\ of\ sample} \times 100$$

3.3.1.11 Textural analysis

Textural attributes such as firmness, stickiness, work of adhesion and work of shear, were determined by single compression method using a texture analyzer, TA-XT2i (M/s Stable Micro Systems, UK) fitted with a 25 kg load cell. The load cell was calibrated with 5 kg standard dead weight prior to use. For determining the textural attributes, the pasteurized and cooled APD mix was filled in pre-sterilized glass beakers (80 g) and incubation was carried out to obtain *dahi*. The *dahi* samples just drawn from the refrigerator (4-5°C) were subjected for texture analysis.

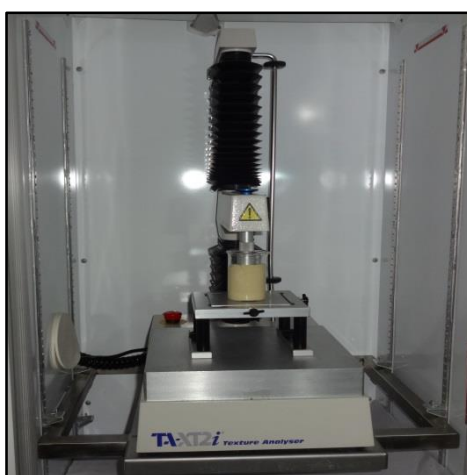


Fig. MM12. Texture analyzer (TA-XT2i) with P25 aluminium probe

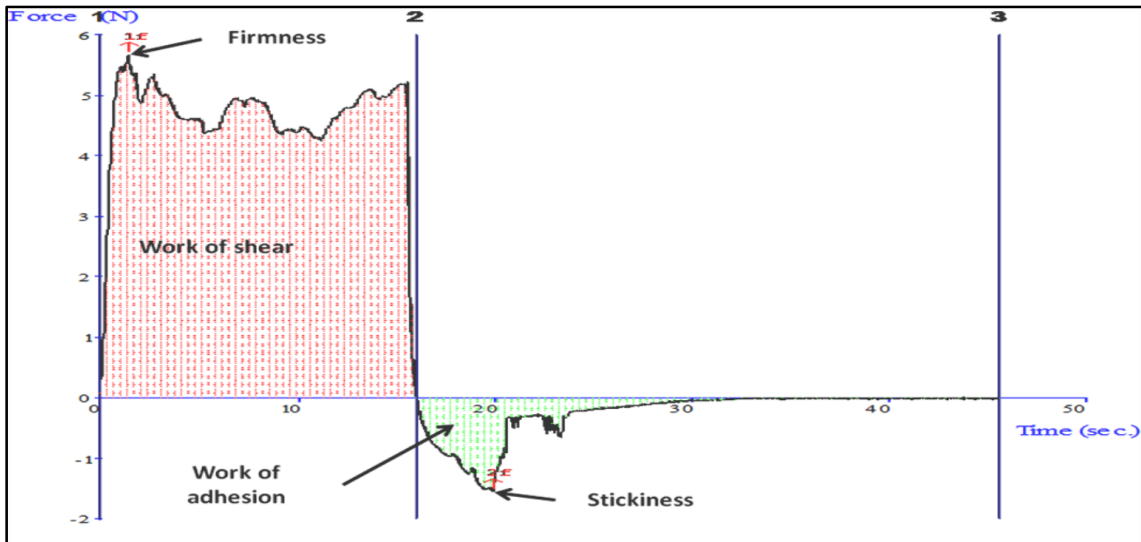


Fig. MM13. Typical force deformation curve of *dahi* in single compression mode

The aluminium probe (P/25) was penetrated up to 40% into the set *dahi* at a cross head speed of 1.0 mm/sec. The pre- and post- test speeds of the probe were adjusted to be 2.0 mm/ sec. From the resulting force-time curves, firmness i.e., the force for compression (N), stickiness i.e., the negative peak force (N) during withdrawal, work of shear (N.s) and work of adhesion (N.s) were calculated using the Texture Expert Exceed software (version 2.55) supplied by the manufacturer along with the instrument.

3.3.2 Chemical Parameters

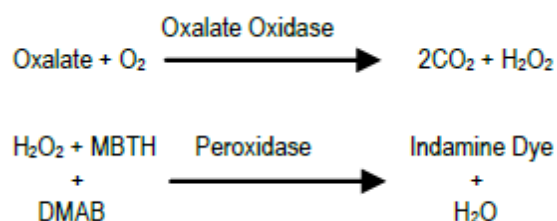
3.3.2.1 Oxalate (total and soluble) content

Prior to oxalate estimation the yam paste was thawed and then homogenized in food processor. Oxalate was extracted from EFY paste as per the procedure described by Okombo and Liebman (2010) with minor modifications.

For total oxalate extraction, about 10 g sample was weighed into a 250 ml Erlenmeyer flask with 50 ml of 2 M HCl. The flask was covered with aluminium foil and placed into water bath (Laboratory Glassware Co., Ambala Cantt., India) at 75°C for 30 min with intermittent swirling (5 min interval). The flask was then allowed to cool and 50 ml of deionised water was added and swirled. The mixture was then filled in plastic centrifuge tubes and centrifuged (SIGMA Laborzentrifugen, 2-16 PK, Osterode am Harz, Germany) for 10 min at 3000 rpm.

The supernatant was then filtered into plastic vials and refrigerated prior to oxalate analysis.

For soluble oxalate, same amount of sample was weighed in 250 ml Erlenmeyer flask with 50 ml of distilled deionised water. The remainder of the extraction procedure was identical to that for total oxalate.



The extracted samples were then analyzed for oxalate using the oxalate kit (Trinity Biotech Co., Wicklow, Ireland). This method is based on oxidation of oxalate by oxalate oxidase, followed by detection of hydrogen peroxide (H₂O₂) produced during the reaction by a peroxidase-catalyzed reaction (MBTH- 3-methyl-2-benzothiazolinone hydrazone; DMAB- 3-(dimethyl amino) benzoic acid).

3.3.2.2 Solids loss

Solid loss in soak/ cook water was determined by the gravimetric method as described in AOAC (2000). A dry, empty and clean dish was weighed. About 10 ml of soak water was taken in the dish and weighed accurately. The dishes were kept in hot air oven at 105°C for until constant weight (about 5 hour). After drying the samples in the oven, they were transferred into desiccators to cool for 30 min and then weighed accurately.

3.3.2.3 Proximate composition

3.3.2.3.1 Fat

The fat percent of buffalo milk was estimated by the Gerber method described in IS: SP: 18, Part XI (1981). The fat content of yam *dahi* was determined by Mojonnier method (Laboratory Manual, 1959).

3.3.2.3.2 Total solids

The total solids content of APL was estimated by gravimetric method as per the procedure described in IS: SP: 18, Part XI, (1981).

3.3.2.3.3 Protein content

The protein content was estimated by Microkjeldahl method given by AOAC (1995).

3.3.2.3.4 Ash

The ash content of APL samples was estimated by the method described in IS: SP: 18 Part XI, (1981).

3.2.2.2.5 Dietary fibre

The crude fibre was estimated in defatted raw sample and selected powder by using Fibraplus, Pelican Equipments, India. Accurately weigh 1 g defatted sample in the extraction crucibles. The crucible was inserted in to the hot extraction system and the sample was digested in 1.25% sulphuric acid. The sample was first boiled with acid at 550⁰C and kept for digestion at 450⁰C for 45 min. After digestion, the acid was filtered through the crucible and the sample was rinsed with distilled water. The same procedure was repeated for alkali digestion using 1.25% sodium Hydroxide solution. The sample crucibles were kept in the oven maintained at 102⁰C for 1 h to remove moisture and kept for ashing in the muffle furnace at 450⁰C for 4 h.

$$\text{Crude fibre (\%)} = \frac{W_2 - W_1}{W} \times 100$$

where, weight of sample (in g) = W ; residue (crude fibre + mineral matter) (in g) = W₁ ; weight after ashing (in g) = W₂

3.3.2.4 Total phenol and DPPH activity of yam paste

Hydro-methanolic extract was prepared for determination of phenolic content and DPPH (2, 2 diphenyl-1-picryl hydrazyl) activity of yam paste. About 10 g of cooked paste was weighed in a conical flask and 50 ml of 80% methanol was added. It was shaken for 1 h. The solution was then centrifuged at 4000 rpm for 30 min. The supernatant was collected and extraction was repeated. The supernatant was pooled and stored at -20⁰C till analysis.

The total phenolic content was determined using the method of Cordenunsi *et al.* (2004). The prepared extract 500 µl was mixed with 2.5 ml 0.2 N Folin's reagent and incubated at room temperature for 5 min. Saturated Na₂CO₃ (75 g/ l) 2.0 ml was added to the mixture and incubated for 90 min at 30⁰C. Absorption of the mixture was taken at 765 nm against a reagent blank. Standard curve was prepared using gallic acid and result was expressed as µg GAE/ g EFY paste.

Antioxidant capacity based on DPPH (2, 2 diphenyl-1-picryl hydrazyl) radical was analyzed following the method given by Brand-Williams *et al.* (1995). 100 µL of

sample was mixed with 4.0 mL of freshly prepared DPPH working solution in 10 mL test tube; the contents were vortexed and incubated in dark for 30 min at 37°C. The absorbance of the solution was measured at 515 nm against methanol. For blank determination, 100 µL methanol was taken instead of sample and absorbance was measured immediately against methanol. DPPH scavenging activity was calculated as:

$$\% \text{ DPPH scavenging activity} = \frac{Abs_{blank} - Abs_{sample}}{Abs_{blank}} \times 100$$

The results were expressed as trolox equivalent antioxidant capacity (TEAC) values i.e. mM of trolox equivalent / g of paste).

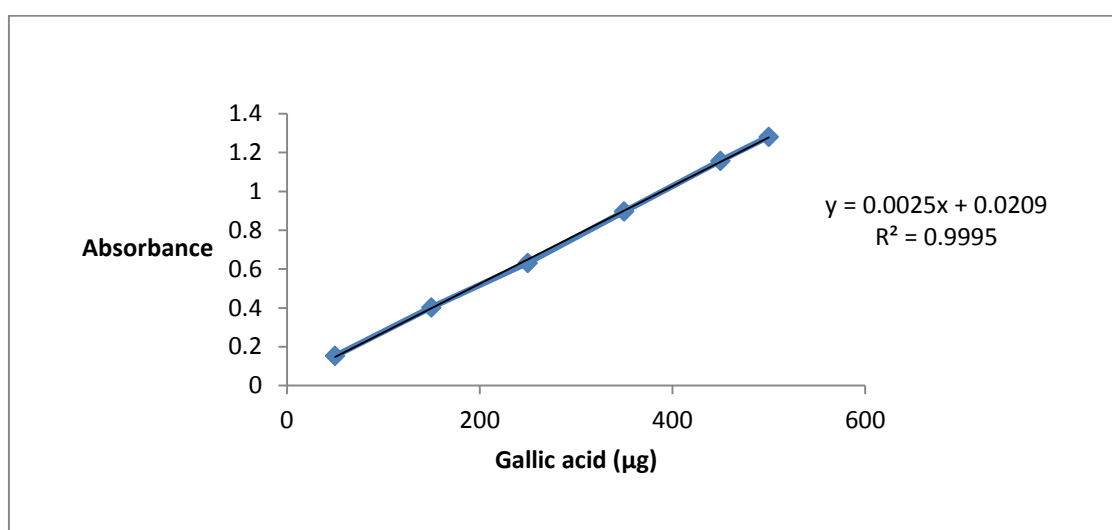


Fig. MM14. Gallic acid standard curve for estimation of total phenolic content

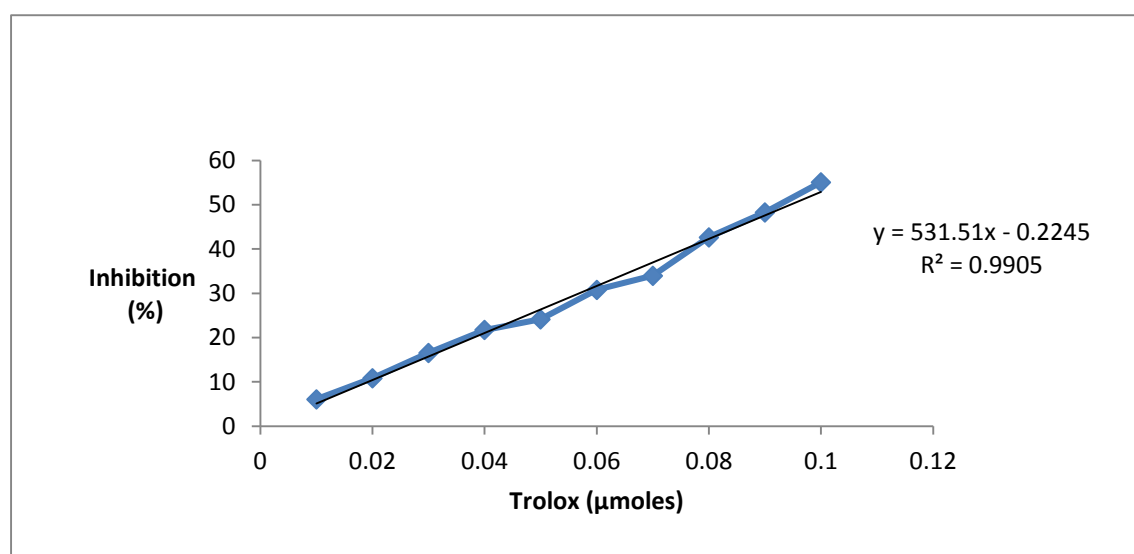


Fig. MM15. Trolox standard curve by DPPH method

3.3.2.5 Total phenolic content, DPPH and ABTS activity of yam powder

The total phenolic content, DPPH activity and ABTS activity of yam powder and *dahi* powder was determined, both for, methanolic extract and water extract. 1 g of sample was weighed and dispersed in methanol (100%). The mix was shaken for 1 h. The solution was then centrifuged at 4000 rpm for 30 min. The supernatant was collected and stored at -20°C till analysis. For water extract the sample was dispersed in water and the extraction process was repeated.

The total phenolic content was determined using the method of Kahkonen *et al.* (1999). 400 µl of appropriately diluted sample/ gallic acid standard was taken in a test tube. To it added 2000 µl of diluted Folin-Ciocalteu's reagent and mixed with vortex mixer. After 3 minutes 1600 µl of sodium carbonate solution was added and incubated under dark at room temperature for 30 min. For blank preparation 400 µl of distilled water was taken instead of sample. The absorbance of the sample was measured against blank at 765 nm.

Standard curve was prepared using gallic acid. Based on absorbance the total phenol content of sample was calculated using equation of standard curve,

$$y = 0.0271x - 0.005; R^2 = 0.99$$

where, y is absorbance at A_{765} (sample), x is concentration of gallic acid (µg/ ml). The results were expressed as µg GAE/ g sample.

Antioxidant capacity based on DPPH (2, 2 diphenyl-1-picryl hydrazyl) radical was analyzed following the method given by Brand Williams *et al.* (1995). 100 µl of appropriate dilution of sample solution was mixed with 3.9 ml of freshly prepared DPPH working solution in 10 ml test tube; the contents were mixed with vortex stirrer and incubated in dark for 120 min at 37⁰ C after covering the test tube with aluminium foil. The absorbance of the solution was measured at 515 nm. For blank determination 100 µl methanol was taken instead of sample and absorbance was measured immediately against methanol. Based on percent inhibition of absorbance of sample, trolox equivalent was determined using following standard curve equation:

$$y = 5249.9x - 0.7421; R^2 = 0.99$$

where, y is the percent inhibition, x is the concentration of trolox (mM). The results were expressed as trolox equivalent antioxidant capacity (TEAC) values i.e. mM of trolox equivalent / g sample).

Antioxidant capacity based on ABTS (2, 2'-azinobis (3 ethyl benzo thiazoline) was analyzed following the method given by Re *et al.* (1999) with modifications. 2 ml of ABTS working solution prepared with methanol was added to quartz cuvette and 20 μ l of sample was added to both reference cuvette (containing 2 ml methanol) and sample cuvette (containing 2 ml ABTS working solution). The contents of sample cuvette were mixed for 10 seconds and decrease in absorbance at 734 nm was recorded over period of 6 minutes at 10 sec interval. Based on per cent inhibition of absorbance of sample, trolox equivalent was determined from the following standard curve equation:

$$y = 23877x - 2.525; R^2 = 0.98$$

where, y is the percent inhibition –

$$Inhibition(\%) = \frac{Abs_{734\ control} - Abs_{734\ sample}}{Abs_{734\ control}} \times 100$$

and x is the concentration of trolox (mM). The results were expressed as trolox equivalent antioxidant capacity (TEAC) values i.e. mM of trolox equivalent / g sample).

3.3.3 Sensory Evaluation

3.3.3.1 Sensory evaluation of yam-milk mix

For sensory evaluation, 10% (w/v) of yam-milk mix was prepared by mixing 100 g of yam paste in 1000 ml of toned milk using hand blender (DX-505, Lee Handy, Leema Industries, India) at 12000 rpm for 2 min. The prepared mix was evaluated for sensory characteristics by a panel of judges selected from the Division on a 9-point hedonic scale (Annexure-2). The panel members were asked to judge for colour and appearance, flavour, acidity and mouthfeel.

3.3.3.2 Hand sensed acidity of yam paste

Yam paste was evaluated for sensory acidity by a panel of judges (Age: 23-28 years) selected from the Division using a 5 point semi-structured acidity evaluation card (Annexure-1). The panel members were asked to judge the acidity after applying the yam paste on the soft part (inside) of the forearm for 3-4 min for feeling the itchy sensation if any, and make a “vertical mark” along, giving the relevant sample numbers to indicate the intensity of acidity (0- no acidity, 4- extreme acidity).

3.3.3.3 Sensory evaluation of dahi and lassi

Sensory evaluation of *dahi* prepared was carried out with 5 point scheme as given by Tamime and Robinson (1999). Sensory evaluation of different samples of the *lassi* was carried out using 9-point Hedonic scale (Stone *et al.* 1974). Sensory evaluation panel consisted of ten judges having adequate knowledge about the sensory evaluation methods and product characteristics were chosen from the Dairy Technology Division of NDRI, Karnal. The samples were drawn from the refrigerator just before serving to the panellists. The sensory score cards served for the panellists during the sensory evaluation of the *dahi* and *lassi* samples are presented in Annexure-6 and Annexure-7, respectively.

3.3.4 Consumer Response Study and Cost Analysis of Yam-Dahi

The developed product was given to people of different age groups of either sex and was evaluated for its consumer response. Their response on acceptability of the product was recorded. The questionnaire used for the consumer response study is depicted in Annexure- 8. The cost analysis of the yam blended *dahi* was calculated as per Sharique (2013). The prevailing price of all ingredients was used to estimate the cost. The electrical power requirement, along with cost of major raw materials and equipments are given in Annexure 9 and Annexure 10.

3.3.5 Statistical Analysis

The data obtained from factorial experiments were analyzed by analysis of variance (ANOVA) (factorial ANOVA and one way ANOVA) using IBM SPSS Statistics version 20. Significant differences between means were determined using Tukey's honestly significant difference (HSD) test. Significant differences were determined at 95% and 99% confidence level. The data from response surface methodology experiments were analyzed using Design Expert version 7.0.0 and Design Expert version 8.0.5.2. (Statease Inc., Minneapolis, Minnesota, USA). The t-test for two samples assuming equal variance was applied using Microsoft Excel for comparison of the predicted values with the actual values.

CHAPTER - 4

Results and Discussions

4. RESULTS AND DISCUSSION

Nowadays, foods providing additional nutritional and disease-preventing qualities are invigorating the world's food industry. Health conscious consumers are gravitating towards healthier segment of food that aims to promote better health, increase longevity and prevent the onset of chronic diseases. These so called 'Functional Foods' as defined by European Commission's Concerted Action on Functional Food Science, improves health and well-being of humans and/ or causes disease risk reduction by beneficially affecting the bodily functions. These foods, instead of a pill, capsule or dietary supplement, are consumed as part of normal diet (FUFOSE, 1999). Because of their consumption as a regular component of meals, this segment enjoys worldwide consumer support and is therefore growing at a brisk rate. In India *dahi* and *lassi* have been the major fermented dairy products from time immemorial and these are regularly consumed by wide section of population. Thus, these products offer an excellent carrier medium for better outreach of any value addition. In the present study, elephant foot yam (EFY), an underutilized tuber having wide recognition in *Ayurveda* was incorporated in *dahi* and *lassi* due to its numerous medicinal utilities and therapeutic values. The present chapter deals with the detailed discussion of the same. The results along with relevant discussions are reported in this chapter under the following major heads:

1. Processing of EFY to make it compatible in dairy foods.
2. Properties of fermented dairy foods viz. *dahi* and *lassi* blended with EFY.
3. Evaluation of EFY containing *dahi* for shelf life.

4.1 PROCESSING OF ELEPHANT FOOT YAM TO MAKE IT COMPATIBLE IN DAIRY FOODS

Elephant foot yam is inherently acrid in nature, presumably due to presence of a composite of oxalate crystals (raphides) (Bradbury and Holloway, 1988; Saikia and Borah, 1994) and a chemical irritant, which is either a diglucoside of 3,4-dihydroxy benzaldehyde (Saha and Hussain, 1983; Suzuki, 1980), an unidentified proteinase (Bradbury and Hammer, 1990; Fochtman *et al.* 1969), or a hormone or sapotoxin (Walter and Khanna, 1972). Apart from acting as an irritant, oxalates have their own repercussions on human body, the major effects being deposition of calcium oxalate crystals in the kidneys (Connor,

1977), occurrence of renal stones (Passmore and Eastwood, 1986) and reduction in bioavailability of calcium (Hodgkinson, 1977; Kelsay, 1985). Acridity itself is a painful experience of severe itching, stinging or burning sensation in the mouth and throat, which may be followed by swelling. Processing is one of the best means employed for making foods more palatable and less toxic. Various detoxification techniques i.e. heating, pH change, soaking, physical processing, drying, fermentation etc. are used for plant foods to render them edible for humans (Johns and Kubo, 1988). These processes have their own mechanism by which they help in detoxifying foods. Three different pre-soaking treatments viz. alkali soaking, saline soaking and acidulated saline soaking combined with cooking were tried for their effectiveness in mitigating the dual acridity-oxalate problem. The pre-soaked and cooked EFY was evaluated for Hunter colour parameters, oxalate content and acridity; the yam was further mixed with milk and evaluated for sensory attributes-colour, flavour, acridity and mouthfeel.

4.1.1 Effect of alkaline pre-soaking on properties of cooked EFY and EFY-milk mix

4.1.1.1 Effect of alkaline soaking (NaOH) treatment on Hunter colour parameters (L^ , a^* , b^*) and whiteness index (WI) of paste obtained from pre-soaked and cooked elephant foot yam*

Colour is the perception in the brain that results from the detection of light after it has interacted with an object. In Colorflex spectro-colorimeter, colour is read in terms of Hunter L^* , a^* and b^* values based upon 'opponents colour theory' and all three values are required to completely describe an object's colour. The pre-soaked and cooked EFY paste was subjected to colour analysis. The Hunter L^* value, suggesting 'whiteness' (or 'blackness'), of EFY paste varied from 43.67 to 53.20 (Table RD1). The alkali concentration ($p \leq 0.01$), soaking time ($p < 0.05$) and their interaction ($p < 0.01$) affected the L^* value (Table RD5). In general L^* value decreased with increasing soaking time and increasing alkali concentration. Longer soaking time and higher NaOH concentration tended to make the yam paste darker. However, at the lowest concentration of the NaOH solution, the soaking time had an opposite effect and, as a result, the mean L^* value was significantly higher than that for control (plain soak water). Hunter a^* value of the EFY paste was found to be significantly affected (Table RD5) by alkali concentration ($p \leq 0.01$) and the pre-soaking time ($p \leq 0.05$).

Table RD1. Hunter L* value[#] of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Alkali Concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	50.34±0.78	50.29±0.12	50.39±0.34	50.34 ^b
0.01	51.64±0.27	52.83±0.17	53.20±0.45	52.55 ^c
0.05	50.85±1.09	50.73±0.19	49.61±0.40	50.40 ^b
0.10	48.17±0.55	46.25±0.59	43.67±0.55	46.03 ^a
Mean	50.25 ^A	50.02 ^{AB}	49.22 ^{BC}	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD2. Hunter a* value[#] of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Alkali Concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	9.95±0.19	9.81±0.16	10.66±0.24	10.14 ^a
0.01	10.30±0.10	8.70±0.00	8.89±0.14	9.30 ^a
0.05	10.35±0.79	9.29±0.46	10.28±0.18	9.97 ^a
0.10	11.42±0.14	11.32±0.34	11.85±0.84	11.53 ^b
Mean	10.51	9.78	10.42	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD3. Hunter b* value[#] of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Alkali Concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	24.46±0.34	24.40±0.28	24.45±0.45	24.44 ^b
0.01	24.98±0.44	26.05±0.91	24.41±0.59	25.15 ^b
0.05	25.03±0.85	25.75±0.89	24.25±0.24	25.01 ^b
0.10	23.31±0.69	23.02±0.29	22.16±0.42	22.83 ^a
Mean	24.45	24.80	23.82	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD4. Whiteness value (or, Whiteness Index, WI)[#] of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min

Alkali Concentration (%)	Pre-soaking time (in min)			Mean
	60	90	120	
0.00	43.76±0.87	43.76±0.26	43.67±0.06	43.73 ^b
0.01	44.60±0.42	45.42±0.58	46.47±0.15	45.49 ^c
0.05	43.88±0.73	43.64±0.65	43.14±0.49	43.55 ^b
0.10	42.03±0.24	40.44±0.48	38.32±0.51	40.26 ^a
Mean	43.56	43.31	42.90	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Alkali concentration also displayed a significant effect on Hunter b* value (Table RD5) of cooked EFY paste. With rising alkali level the yellowness as depicted by the Hunter b* component, decreased highly significantly ($p \leq 0.01$) although the yam derived from plain-water soaked yam was lower the on yellowness scale (Table RD3). The three Hunter Lab parameters can be effectively integrated into a single value Whiteness Index (WI), which distinctly expresses the colour or whiteness of a product. WI, which measures the discoloration of the product, significantly decreased (Table RD5) with increasing alkali concentration, apparently due to the development of browning intermediates. Alkaline conditions are known to favour the enolization process, which leads to the transformation of sugars into Maillard reaction products (MRP's) (Yang and Montgomery, 1996; Kim and Lee, 2008). Further, the temperature also acts synergistically with alkaline conditions in speeding up the enolization transformation, as browning and other intermediate reaction products increase with heating (Benjakul *et al.* 2005).

Not only Maillard reaction, but caramelization process also contributes to non-enzymatic browning, especially in alkaline conditions (Ajandouz and Puigserver, 1999; Ajandouz *et al.* 2001). A small decrease in WI was also observed with increasing soaking length (Table RD4), thereby reflecting the impact of alkaline soaking on L*, a* and b* values of the product.

Table RD5. ANOVA for changes in Hunter colour parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in NaOH solution of different concentrations for varying periods

Source	Dependent variable	df	F-value
Corrected model	L* value	11	25.638**
	a* value		6.298**
	b* value		3.587*
	WI		18.226**
Alkali concentration	L* value	3	79.307**
	a* value		17.040**
	b* value		9.988**
	WI		55.221**
Time	L* value	2	4.164*
	a* value		4.073*
	b* value		2.940
	WI		1.741
Alkali concentration x Time	L* value	6	5.962**
	a* value		1.668
	b* value		0.602
	WI		5.223**
Error	L* value	12	
	a* value		
	b* value		
	WI		

*p<0.05, **p<0.01

4.1.1.2 Effect of alkaline (NaOH) pre-soak on oxalate content and hand-sensed acidity of cooked EFY paste

Oxalate content of any food is of utmost significance, because of its adverse influence on human health. The oxalate content of yam paste obtained from alkali pre-soaked, cooked EFY varied from 89.78-95.24 mg/100 g (Table RD6). It was not significantly affected either by alkali concentration or soaking duration (Table RD8). The reduction in oxalate content ranged from 18.77-23.43%.

Table RD6. Oxalate content (mg/100 g)[#] of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Alkali concentration (%)	Pre-soaking time (in min)			Mean
	60	90	120	
0.00	94.82±1.12	94.17±1.19	94.83±0.16	94.61
0.01	95.24±2.13	94.04±0.92	94.44±3.1	94.57
0.05	95.79±2.67	91.58±0.09	91.98±0.22	93.11
0.10	89.78±1.07	92.99±1.40	92.85±1.41	91.87
Mean	93.90	93.19	93.52	93.54

[#] Mean ± SE from 2 replicates

Cooking is known to reduce the oxalates in the food by thermal degradation and consequent leaching losses into the cooking water (Wanasundera and Ravindran, 1994; Savage *et al.* 2000; Albihn and Savage, 2001). Judprasong *et al.* (2006) reported losses ranging from 18% to 76% in various Thai foods due to cooking by boiling. Boiling has been reported to be effective in reducing the oxalates in various foods i.e. yam tubers (Wanasundera and Ravindran, 1992), *colocasia* (Iwuoha and Kalu, 1995), spinach (Bakr and Gawish, 1997), wild yam (Bhandari and Kawabatta, 2006), Japanese taro (Catherwood *et al.* 2007), etc.

Table RD7. Hand-sensed acidity score[#] of EFY paste of the yam pre-soaked in NaOH solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Alkali concentration (%)	Pre-soaking time (in min)			Mean
	60	90	120	
0.00	1.0±0.0	1.0±0.0	1.1±0.1	1.03 ^b
0.01	1.1±0.1	0.7±0.1	0.8±0.2	0.83 ^b
0.05	0.6±0.1	0.6±0.0	0.5±0.1	0.57 ^a
0.10	0.4±0.1	0.5±0.0	0.4±0.1	0.45 ^a
Mean	0.78	0.69	0.7	

[#] Mean ± SE from 2 replicates; means with different superscript are significantly different as determined by Tukey's test; Acridity score measured on 5 point semi-structured 5 point linear scale (0-4), where 0- no acridity and 4 - extreme acridity

Acridity i.e. itchiness felt upon consumption of EFY was determined by hand sensing technique as prescribed by Saha and Hussain (1983). Acridity in

yam as perceived by sensory panellists decreased significantly ($p \leq 0.01$) (Table RD7, RD8) with increasing alkali concentration. Soaking time appeared to affect the acidity non-significantly. Tu (1981) used aqueous alkali to remove acrid principles from the aroid corms and the edibles further prepared from them were found, not to irritate mucous membranes in the mouth and throat. Similar effects were reported by Huang and Hollyer (1995), who used alkali soaking for removing acidity from Araceae tubers.

4.1.1.3 Effect of alkali pre-soaking of EFY on sedimentation in yam-milk dispersion obtained by blending pre-soaked and cooked EFY with milk

Sedimentation is the tendency of particles in suspension to settle out of the fluid in which they are entrained. Sedimentation of yam-milk dispersion ranged from 0.20-0.24 (Table RD9).

Table RD8. ANOVA for changes in oxalate content, hand-sensed acidity score of cooked EFY (30 min boiling) paste and sedimentation in yam-milk dispersion of EFY pre-soaked in NaOH solution of different concentrations for varying periods

Source	Dependent variable	df	F-value
Corrected model	Oxalate concentration	11	1.25
	Hand-sensed acidity score		9.379**
	Sedimentation		1.50
Alkali concentration	Oxalate concentration	3	2.097
	Hand-sensed acidity score		28.448**
	Sedimentation		0.5
Time	Oxalate concentration	2	0.205
	Hand-sensed acidity score		1.229
	Sedimentation		6.0*
Alkali	Oxalate	6	1.175

concentration × Time	concentration		
	Hand-sensed acridity score		2.562
	Sedimentation		0.5
Error	Oxalate concentration	12	
	Hand-sensed acridity score		
	Sedimentation		

*p<0.05, **p<0.01

Sedimentation coefficient (residue remaining after centrifugation; expressed as per gram of sample) of the yam-milk mix was significantly ($p \leq 0.05$) affected by soaking time, but not by the alkali concentration (Table RD8).

Table RD9. Sedimentation[#] of the EFY-milk dispersion from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time

Alkali concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	0.21±0.01	0.20±0.00	0.22±0.01	0.21
0.01	0.22±0.00	0.20±0.00	0.23±0.01	0.22
0.05	0.21±0.00	0.21±0.01	0.24±0.01	0.22
0.10	0.22±0.01	0.21±0.01	0.22±0.01	0.22
Mean	0.22 ^{AB}	0.21 ^A	0.23 ^B	

Mean ± SE from 2 replicates; means with different superscript are significantly different as determined by Tukey's test

4.1.1.4 Sensory characteristics of yam-milk mix prepared from alkali-pre-soaked and cooked yam

A 10% dispersion of cooked yam in milk (fat, 3%; MSNF, 8.5%) was subjected to sensory evaluation using a 9-point hedonic scale. The main objective was to figure out if acidity was perceived in plain yam-milk dispersion/beverage and also to judge other sensory attributes viz., appearance, flavour and mouth-feel of the yam-milk blend.

The colour and appearance score of yam-milk mix was adversely affected ($p \leq 0.05$) by alkali pre-soaking (Tables RD10 & RD14). The colour and

appearance score of dispersion decreased from 6.67 to 6.18 with increased alkali level from 0.01 to 0.10%. The soaking time appeared not to significantly affect the appearance of the yam-milk mix. The colour and appearance score appeared to be well in agreement with Hunter L* value and whiteness index ($r = 0.65$) in terms of the effect of the alkali concentration. Thus, the browning effect of alkaline soaking had a negative impact on the appearance of the yam-milk mix.

Flavour score of the yam-milk dispersion followed a trend similar to that in respect of appearance. It was adversely affected ($p \leq 0.05$) by increasing alkali concentration (Table RD11). The score decreased from 6.72 to 6.26 with the alkali level increasing from 0.01 to 0.10%. Neither the soaking period nor the interaction effect of process variables significantly altered the flavour score of yam-milk blend.

The acidity perceived in the yam-milk mixture was significantly ($p \leq 0.05$) affected by the alkali treatment (Table RD12). With respect to the soaking time, the acidity score showed no significant effect (Table RD12). The interaction effect of the process variables was also observed to be non-significant (Table RD10).

The mouthfeel score of yam-milk mix varied from 7.06 to 5.75 (Table RD 13) on a 9-point hedonic scale. The process factors i.e. alkali concentration and pre-soaking time and their interaction showed no significant effects (Table RD13) on the mouthfeel score of yam-milk dispersion.

Table RD10. Sensory colour and appearance score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time

Alkali concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	6.57±0.18	6.71±0.09	6.65±0.07	6.64 ^b
0.01	6.74±0.06	6.68±0.02	6.60±0.15	6.67 ^b
0.05	6.60±0.12	6.67±0.05	6.52±0.08	6.60 ^b
0.10	6.11±0.18	6.21±0.29	6.21±0.24	6.18 ^a
Mean	6.51	6.57	6.50	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD11. Sensory flavour score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time

Alkali concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	6.43±0.07	6.68±0.05	6.46±0.34	6.52 ^{ab}
0.01	6.89±0.14	6.86±0.04	6.42±0.12	6.72 ^b
0.05	6.31±0.08	6.41±0.14	6.73±0.07	6.48 ^{ab}
0.10	6.42±0.16	6.31±0.21	6.04±0.24	6.26 ^a
Mean	6.51	6.57	6.41	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD12. Sensory acidity score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of alkali concentration and time

Alkali concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	7.14±0.14	7.29±0.14	7.07±0.02	7.17 ^b
0.01	7.04±0.10	7.00±0.08	6.75±0.08	6.93 ^{ab}
0.05	7.17±0.15	7.00±0.10	6.97±0.18	7.05 ^{ab}
0.10	6.79±0.06	6.61±0.19	6.91±0.11	6.77 ^a
Mean	7.04	6.98	6.93	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

4.1.2 Effect of Saline Pre-Soaking on Properties of Cooked EFY and EFY-Milk Mix

4.1.2.1 Effect of saline pre-soaking on Hunter colour parameters (L, a*, b*) and whiteness index (WI) of cooked yam paste*

Pre-soaking in saline solution was expected to salt out or inactivate the acid components present in EFY. Hence, saline solution of different concentrations (2%, 6% and 10%) was used in pre-soaking of EFY for varying periods. The Hunter L* value of EFY paste was significantly affected by salt concentration ($p \leq 0.01$) (Table RD19).

Table RD13. Sensory mouthfeel score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of saline concentration and time

Alkali concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0.00	6.93±0.08	6.89±0.06	6.86±0.06	6.89
0.01	7.06±0.04	6.82±0.03	6.68±0.13	6.85
0.05	6.70±0.11	6.44±0.13	6.86±0.12	6.68
0.10	6.83±0.11	6.56±0.21	5.75±0.15	6.71
Mean	6.88	6.73	6.75	

Mean ± SE from 2 replicates

Table RD14. Hunter L* value[#] of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	50.34±0.78	50.29±0.12	50.39±0.34	50.34 ^a
2	49.90±0.29	51.30±0.44	51.54±0.57	50.91 ^{ab}
6	51.54±0.77	53.66±0.68	51.69±0.73	52.30 ^b
10	51.94±0.96	49.81±0.30	48.60±0.51	50.12 ^a
Mean	50.93	51.27	50.56	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

It increased with increasing salt concentration up to 6 % but then declined at 10% concentration (Table RD15), the interaction between salt concentration and pre-soaking duration being significant ($p \leq 0.05$) (Table RD15). The soak time had as such no significant effect on the L* value.

Table RD15. ANOVA for changes in sensory parameters of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different combination of saline concentration and time

Source	Dependent variable	Df	F-value
Corrected model	Colour and appearance score	11	2.127
	Flavour score		2.335

	Acridity score		2.444
	Mouthfeel score		0.244
Alkali concentration	Colour and appearance score	3	7.239**
	Flavour score		4.162*
	Acridity score		5.754*
	Mouthfeel score		0.107
Time	Colour and appearance score	2	0.275
	Flavour score		0.909
	Acridity score		0.813
	Mouthfeel score		0.162
Alkali concentration × Time	Colour and appearance score	6	0.188
	Flavour score		1.897
	Acridity score		1.332
	Mouthfeel score		0.586
Error	Colour and appearance score	12	
	Flavour score		
	Acridity score		
	Mouthfeel score		

*p<0.05, **p<0.01

Table RD16. Hunter a* value# of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	9.95±0.19	9.81±0.16	10.66±0.24	10.14 ^c
2	9.95±0.06	9.64±0.24	8.95±0.09	9.51 ^b
6	8.95±0.56	8.39±0.07	8.73±0.31	8.68 ^a
10	8.95±0.32	10.96±0.16	10.36±0.24	10.09 ^{bc}
Mean	9.45	9.70	9.68	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD17. Hunter b* value[#] of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	24.46±0.34	24.40±0.28	24.45±0.45	24.44 ^a
2	24.75±0.07	24.81±0.69	26.13±0.21	25.23 ^{ab}
6	26.13±0.68	26.81±0.31	26.38±1.20	26.44 ^{ab}
10	26.16±0.46	25.58±0.43	25.36±0.12	25.70 ^b
Mean	25.37	25.40	25.58	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Although, salt (sodium chloride) is known to be an effective browning inhibitor (Pilizota and Subaric, 1998) as it inhibits the polyphenol oxidases (PPOs), the property is concentration dependent. For apples, Pizzicaro *et al.* (1993) noticed 0.02-0.1% concentration to be activating for apple PPOs, whilst Tafel and Voigt (1964) observed 0.5-1.0% salt concentration to be inhibitory for browning. Thus, the increase in the L* value for up to 6% salt concentration may be attribute to reduced polyphenol oxidase activity at this salt concentration. However, a much higher concentration (20%) is usually needed for inactivation of PPOs as pointed out by Ponting and Joslyn (1948).

Table RD18. Whiteness index[#] of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min in boiling water

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	43.76±0.87	43.76±0.26	43.67±0.06	43.73 ^{ab}
2	43.24±0.22	44.50±0.04	44.22±0.61	43.99 ^{ab}
6	44.22±0.90	45.81±0.72	44.25±0.11	44.76 ^b
10	44.55±1.10	42.61±0.04	41.76±0.54	42.97 ^a
Mean	43.94	44.17	43.47	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

The decrease in L* value using 2% or 10% saline soaking treatment possibly indicates some kind of complex mechanism inducing the colour change instead of PPO inhibition.

The Hunter a* value of the cooked-yam paste derived after salt pre-soaking was significantly influenced by salt concentration ($p \leq 0.01$) (Table RD19). As compared to the L* value, a* value followed a reverse trend and at 6% salt concentration a* was minimum (Table RD17), which suggested a decrease in redness and, conversely, an increase in greenness.

However, 10% salt concentration resulted in a* value almost the same as control, which indicated that the interaction between concentration and soak time was significant ($p < 0.01$) (Table RD19). Hunter b* value of the saline-soaked cooked EFY paste was considerably altered ($p \leq 0.01$) by salt concentration and, like L* value, it increased to a maximum in 6% salt pre-soaked product but declined appreciably when 10% salt pre-soak was used (Table RD17). The whiteness index, which gives a combined picture of all three hunter colour parameters followed a trend identical to Hunter L* value.

Thus, the Hunter colour parameters showed a tendency of attaining either a maximum (L*, b* & WI) or a minimum (a*) in yam pre-soaked in 6% salt solution. The cause of such behaviour could either be related to the activity of polyphenolase enzymes from EFY or any unknown change that might be occurring during the cooking process.

4.1.2.2 Effect of saline pre-soak on the oxalate content and hand-sensed acidity of cooked EFY paste

As indicated in Table RD20, the oxalate content present in EFY after salt pre-soaking and cooking treatment varied from 93.85 to 102.30 mg/100 g. The oxalate level was not significantly affected either by salt level used in the pre-soaking treatment or the pre-soaking duration. As no significant difference was noticed between oxalate content of paste obtained after water soaking-cooking process and salt water soaking-cooking process, the degradation in oxalate content can be considered wholly by hydrothermal effect (Iwuoha and Kalou, 1995).

Boiling itself is an effective process in degrading the oxalates and leaching them into cook water (Savage *et al.* 2000). Thus, salt soaking for 60-120 min

duration appeared to be inconsequential with regard to the reduction in the oxalate level.

Table RD19. ANOVA for changes in Hunter colour parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in saline solution of different concentrations for varying periods

Source	Dependent variable	df	F-value
Corrected model	L* value	11	4.862**
	a* value		10.162**
	b* value		2.676*
	WI		3.071*
Salt concentration	L* value	3	8.218**
	a* value		20.861**
	b* value		7.638**
	WI		4.773*
Time	L* value	2	1.442
	a* value		1.148
	b* value		0.180
	WI		1.467
Salt concentration x Time	L* value	6	4.324*
	a* value		7.817**
	b* value		1.026
	WI		2.755
Error	L* value	12	
	a* value		
	b* value		
	WI		

*p<0.05, **p<0.01

The hand-sensed acidity score of EFY paste obtained from saline pre-soaking and (plain-water) cooking treatment varied significantly ($p \leq 0.01$) with salt concentration and soaking period (Table RD22).

With increasing salt concentration as well as soaking duration, the hand-sensed acidity score showed a rising tendency (Table RD21). This increase in

acridity score suggests an intense itching/ irritation perceived in the presence of salt (taken up during soaking) in the EFY paste.

Table RD20. Oxalate content (mg/100 g)[#] of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	94.82±1.20	94.16±1.16	94.83±0.16	94.60
2	101.00±3.83	93.85±2.00	94.44±3.06	96.43
6	96.76±1.81	94.35±1.17	100.98±2.83	97.36
10	96.91±0.17	102.30±0.80	96.54±1.61	98.58
Mean	97.37	96.16	96.70	

[#] Mean ± SE from 2 replicates

Table RD21. Hand-sensed acridity score[#] of EFY paste of the yam pre-soaked in saline solution of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	1.00±0.00	1.00±0.00	1.10±0.10	1.05 ^a
2	1.15±0.15	1.30±0.10	1.50±0.10	1.32 ^b
6	1.00±0.20	1.20±0.00	1.35±0.05	1.18 ^{ab}
10	1.35±0.05	1.95±0.05	1.75±0.05	1.68 ^c
Mean	1.13 ^A	1.38 ^B	1.43 ^B	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test; Acridity score measured on 5 point semi-structured 5 point linear scale (0-4), where 0- no acridity and 4 - extreme acridity

As discussed above, oxalate which is believed to be main cause of acridity (Sakai, 1979; Sunnell and Healey, 1979; Nixon, 1987; Bradbury and Holloway, 1988; Bradbury and Nixon, 1998) was not affected by salt pre-soaking (followed by cooking) treatment.

Green and Gelhard (1988) reported salt (NaCl) to be producing perceptible sensations of irritation, though in the mouth. Further, salt was shown to increase the burning sensation (a kind of somatosensation similar to irritation which is

produced by thermo-receptors instead of nociceptors) produced by capsaicin in the mouth (Prescott *et al.* 1984).

This phenomenon occurring in the oral cavity could arguably point toward some kind of complex synergistic interaction occurring between irritation perceived due to raphides (oxalates) and residual salt in the EFY paste applied on the skin of forearm which resulted in enhanced acidity sensation.

4.1.2.3 Effect of saline pre-soaking on sedimentation in yam-milk dispersion obtained by blending pre-soaked and cooked EFY with milk

Sedimentation in yam-milk dispersion ranged from 0.19 to 0.22 (Table RD23). It was significantly affected by the salt concentration ($p \leq 0.01$) (Table RD22).

4.1.2.4 Sensory characteristics of yam-milk mix prepared from saline-pre-soaked, cooked yam

The sensory colour and appearance scores of the yam-milk dispersion were significantly affected ($p \leq 0.01$) by the salt concentration used in the pre-soaking treatment (Table RD24). A significant decrease was observed in the colour score with increasing salt concentration; it decreased from 7.15 to 6.78 on a 9 point hedonic scale. The effect of the other process variable was non-significant.

The flavour score of the yam-milk mix significantly decreased with increasing salt concentration ($p \leq 0.01$). The effect of pre-soaking duration or its interaction with salt concentration was non-significant. The flavour score of the dispersion from salt-water pre-soaked yam was lower when compared to that made from yam pre-soaked in plain water. Presumably, the panellists perceived the increased saltiness due to rise in the concentration of salt due to pre-soaking as undesirable.

The sensory acidity score and mouth-feel scores of yam-milk mix were non-significantly affected by the two process variables studied (Table RD24).

Table RD22. ANOVA for changes in oxalate content, hand-sensed acidity score of cooked EFY (30 min boiling) paste and sedimentation in yam-milk dispersion obtained from EFY pre-soaked in saline solution of different concentrations for varying periods

Source	Dependent variable	df	F-value
Corrected model	Oxalate content	11	2.353
	Hand-sensed acidity score		10.225**
	Sedimentation		3.980*
Salt concentration	Oxalate content	3	2.177
	Hand-sensed acidity score		25.492**
	Sedimentation		6.593**
Time	Oxalate content	2	0.378
	Hand-sensed acidity score		11.810**
	Sedimentation		1.056
Salt concentration × Time	Oxalate content	6	3.1*
	Hand-sensed acidity score		2.063
	Sedimentation		3.648
Error	Oxalate content	12	
	Hand-sensed acidity score		
	Sedimentation		

*p<0.05, **p<0.01

Table RD23. Sedimentation[#] of the EFY-milk dispersion from EFY pre-soaked and cooked under different treatment combination of saline concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	0.21±0.01	0.20±0.00	0.22±0.01	0.21 ^a
2	0.22±0.00	0.20±0.01	0.19±0.00	0.20 ^{ab}
6	0.19±0.00	0.19±0.01	0.20±0.00	0.19 ^b
10	0.19±0.00	0.20±0.01	0.19±0.01	0.19 ^b
Mean	0.20	0.20	0.20	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD24. Sensory colour and appearance score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of saline concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	6.57±0.18	6.71±0.09	6.65±0.07	6.64 ^a
2	7.05±0.20	7.30±0.18	7.10±0.20	7.15 ^b
6	6.90±0.05	6.80±0.08	7.00±0.15	6.90 ^{ab}
10	6.90±0.02	6.84±0.08	6.60±0.12	6.78 ^a
Mean	6.86	6.91	6.84	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD25. Sensory flavour score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of saline concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	6.43±0.07	6.68±0.05	6.46±0.34	6.52 ^a
2	7.55±0.32	7.15±0.13	6.98±0.35	7.23 ^b
6	6.60±0.18	6.78±0.05	6.98±0.10	6.79 ^{ab}
10	6.42±0.04	6.28±0.16	6.58±0.12	6.43 ^a
Mean	6.75	6.72	6.75	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD26. ANOVA for changes in sensory parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in saline solution of different concentrations and for varying periods

Source	Dependent variable	df	F-value
Corrected model	Colour and appearance score	11	2.770*
	Flavour score		3.584*
	Acridity score		1.942
	Mouthfeel score		1.724
Salt concentration	Colour and appearance score	3	7.936**
	Flavour score		10.251**
	Acridity score		3.310
	Mouthfeel score		3.190
Time	Colour and appearance score	2	0.364
	Flavour score		0.026
	Acridity score		0.502
	Mouthfeel score		0.213
Salt concentration × Time	Colour and appearance score	6	0.990
	Flavour score		1.437
	Acridity score		1.739
	Mouthfeel score		1.495
Error	Colour and appearance score	12	
	Flavour score		
	Acridity score		
	Mouthfeel score		

*p<0.05, **p<0.01

4.1.3 Effect of acidulated saline pre-soaking (pH 3.5) followed by plain-water cooking on properties of EFY and yam-milk mix

4.1.3.1 Effect of acidulated saline soaking treatment on Hunter colour parameters (L^* , a^* , b^*) and whiteness index (WI) of the yam paste

The Hunter L^* value of acidulated (pH 3.5) salt-water pre-soaked and plain-water cooked EFY paste was significantly ($p \leq 0.01$) influenced by the process variables and their interaction (Table RD33). The Hunter L^* value ranged from 48.60 to 53.66 (Table RD29).

Table RD27. Sensory acidity score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	7.14±0.14	7.29±0.14	7.07±0.02	7.17
2	7.10±0.23	6.75±0.10	6.60±0.32	6.82
6	6.65±0.18	6.80±0.08	6.90±0.20	6.78
10	7.10±0.20	6.68±0.10	7.14±0.02	6.97
Mean	7.00	6.88	6.93	

[#] Mean ± SE from 2 replicates

Table RD28. Sensory mouthfeel score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	6.93±0.08	6.89±0.06	6.86±0.06	6.89
2	6.75±0.16	6.85±0.41	6.81±0.16	6.80
6	6.30±0.22	6.40±0.08	6.80±0.12	6.50
10	6.90±0.12	6.45±0.20	6.40±0.16	6.58
Mean	6.72	6.65	6.72	

[#] Mean ± SE from 2 replicates

Two percent salt soak resulted in a significantly ($p \leq 0.01$) increased L^* value but a small but significant decrease was observed for higher salt concentrations, with-the soak pH remaining constant at 3.5. When the soaking

time was increased from 60 to 90 min, the L* value increased but further increase in time to 120 min led to a lower value. Thus acidulated saline pre-soaked EFY paste was generally better (more light) in colour than water pre-soaked and cooked EFY paste indicating lesser darkening reactions in the former. The lower pH is recognised to hamper the polyphenolase activity (McCord and Kilara, 1983), which is associated with enzymatic reactions causing browning. Phenolase enzymes have been reported to be rendered inactive due to copper-chelating action of citric acid (Jiang *et al.* 1999).

Table RD29. Hunter L* value[#] of EFY paste of the yam pre-soaked in acidulated saline solution of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	50.34±0.78	50.29±0.12	50.39±0.34	50.34 ^a
2	54.36±0.38	55.71±0.61	54.56±0.05	54.88 ^c
6	53.22±0.30	53.38±0.42	53.30±0.11	53.30 ^b
10	54.02±0.59	53.93±0.10	51.63±0.34	53.10 ^b
Mean	52.99 ^{AB}	53.33 ^B	52.40 ^A	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD30. Hunter a* value[#] of EFY paste of the yam pre-soaked in acidulated saline solution of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	9.95±0.19	9.81±0.16	10.66±0.24	10.14 ^c
2	7.41±0.30	7.35±0.06	7.03±0.12	7.26 ^b
6	7.64±0.16	7.11±0.13	6.63±0.18	7.13 ^{ab}
10	6.43±0.06	6.98±0.14	6.77±0.14	6.73 ^a
Mean	7.86	7.81	7.77	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Citric acid has been employed alone or with other chemicals to retard browning in different fruits and vegetables (Langdon, 1987; Santerre *et al.* 1983; Jiang and Fu, 1998; Jiang *et al.* 2004; Tortoe *et al.* 2007).

Table RD31. Hunter b* value[#] of EFY paste of the yam pre-soaked in acidulated saline solution of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	24.46±0.34	24.40±0.28	24.45±0.45	24.44 ^a
2	26.96±0.13	27.44±0.03	27.41±0.04	27.27 ^c
6	25.94±0.21	25.50±0.27	25.70±0.32	25.71 ^b
10	27.97±0.16	27.51±0.22	26.47±0.46	27.32 ^c
Mean	26.83	26.21	26.01	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD32. Whiteness index[#] of EFY paste of the yam pre-soaked in acidulated saline solution of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	43.76±0.87	43.76±0.26	43.67±0.06	43.73 ^a
2	46.48±0.30	47.38±0.51	46.47±0.07	46.77 ^c
6	45.97±0.15	46.39±0.51	46.29±0.27	46.21 ^{bc}
10	45.80±0.59	45.89±0.01	44.19±0.50	45.29 ^b
Mean	45.50	45.86	45.15	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

The Hunter a* value (redness/greenness) of acidulated saline pre-soaked and cooked EFY ranged from 6.77 to 7.64. It decreased significantly with increasing salt concentration in acidulated saline ($p \leq 0.01$) (Tables RD30 & 33). The decline in Hunter a* value (or redness, a component of brown discoloration) suggests decrease in formation of browning intermediates in acidulated saline, presumably due to conjugative effect of sodium chloride and citric acid in lowering the browning reactions (Rouet-Mayer and Philippon, 1986). Hunter a* value also showed a non-significant decrease with increasing pre-soaking time (Table RD30). Hunter b* value (yellowness) of pre-soaked and coked EFY paste varied from 24.46 to 27.97. It was altered in a significant manner ($p \leq 0.01$) by salt concentration of the acidulated saline, as seen in Table RD33. An increase

was observed in the yellowness of acidulated saline pre-soaked and cooked EFY as compared with plain-water pre-soaked and cooked EFY.

Table RD33. ANOVA for changes in Hunter colour parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in acidulated saline solution of different concentrations for varying periods

Source	Dependent variable	df	F-value
Corrected model	L* value	11	21.405**
	a* value		73.870**
	b* value		22.180**
	WI		9.428**
Salt concentration	L* value	3	66.580**
	a* value		257.317**
	b* value		75.094**
	WI		29.924**
Time	L* value	2	5.546*
	a* value		0.253
	b* value		1.416
	WI		2.771
Salt concentration × Time	L* value	6	4.105*
	a* value		6.6868**
	b* value		2.644
	WI		1.399
Error	L* value	12	
	a* value		
	b* value		
	WI		

*p<0.05, **p<0.01

The effect of pre-soaking time was non-significant. The whiteness index, which represents the cumulative effect of all three colour values, was significantly ($p \leq 0.01$) affected by salt concentration in acidulated salt water (Table RD33). It exhibited a trend similar to that in the L* value. The yam paste was less dark

when soaked in acidulated saline and cooked as compared to plain-water soaked and cooked yam (Table RD22). A very slight decrease was observed in whiteness (slight increase in darkness) with increasing salt concentration.

4.1.3.2 Effect of acidulated saline soaking treatment on oxalate content and hand-sensed acidity score of paste obtained from pre-soaked and cooked elephant foot yam

As can be seen from Table RD34, the oxalate content of acidulated saline pre-soaked and cooked EFY paste varied from 92.73 to 97.87 mg/100 g. It was, however, not significantly affected by any of the process variables or their interaction (Table RD 36). The reduction in oxalate content after acidulated saline treatment was akin to the degradation achieved during previous two pre-treatments i.e. alkali pre-soaking and saline soaking.

Table RD34. Oxalate content (mg/100 g)[#] of EFY paste of the yam pre-soaked in acidulated saline of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	94.82±1.12	94.17±1.19	94.83±0.16	94.61
2	97.75±0.43	96.17±2.47	95.36±1.42	96.43
6	92.73±2.09	94.12±0.72	97.87±2.50	94.91
10	96.09±3.63	94.79±0.69	95.19±0.52	95.35
Mean	95.35	94.81	95.81	

[#] Mean ± SE from 2 replicates

Table RD35. Hand-sensed acidity score[#] of EFY paste of the yam pre-soaked in acidulated saline of different concentrations for varying periods followed by cooking for 30 min

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	1.00±0.00	1.05±0.05	1.10±0.10	1.05 ^a
2	1.45±0.25	1.30±0.20	1.25±0.05	1.33 ^{ab}
6	1.10±0.00	1.05±0.05	1.05±0.05	1.07 ^a
10	1.30±0.10	1.35±0.05	1.70±0.20	1.45 ^b
Mean	1.21	1.19	1.28	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

The hand-sensed acidity as evaluated by panellists using a semi-structured, linear scale, showed an increasing tendency with salt concentration. The increase in acidity score was significant one ($p \leq 0.01$) (Table RD36), and the EFY paste became highly irritant. The acidity score of acidulated saline pre-soaked and cooked EFY paste was higher than plain water pre-soaked and cooked EFY paste.

4.1.3.3 Effect of acidulated saline pre-soaking of EFY on sedimentation in yam-milk dispersion obtained by blending pre-soaked and cooked EFY with milk

Sedimentation coefficient of yam-milk blend varied from 0.20 to 0.23. It was significantly affected ($p \leq 0.01$) by salt concentration (Table RD36). An increased salt concentration, especially 6%, resulted in an increased sedimentation (Table RD36). The soaking time and the interaction effect of salt concentration and time did not affect the sedimentation significantly.

Table RD36. Sedimentation[#] of the EFY-milk dispersion from EFY pre-soaked and cooked under different treatment combination of salt concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	0.21±0.01	0.20±0.00	0.22±0.01	0.21 ^a
2	0.21±0.00	0.20±0.00	0.20±0.00	0.20 ^a
6	0.23±0.00	0.23±0.00	0.23±0.01	0.23 ^b
10	0.22±0.01	0.21±0.00	0.22±0.01	0.22 ^a
Mean	0.22	0.21	0.22	

[#] Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

4.1.3.4 Sensory attributes of yam-milk mix prepared from acidulated saline pre-soaked and cooked yam

The data on the sensory characteristics of yam-milk dispersion as influenced by different pre-soaking treatments are in Tables RD38-42.

The colour and appearance score of yam-milk blend was not significantly affected by any of the process variables or their interaction. It varied from 6.61 to 6.86. The sensory flavour score was significantly ($p \leq 0.05$) affected by the salt concentration used in the pre-soaking treatment.

Table RD37. ANOVA for changes in oxalate content, hand-sensed acidity score of cooked EFY paste and sedimentation in yam-milk dispersion obtained from EFY pre-soaked in acidulated saline solution

Source	Dependent variable	df	F-value
Corrected model	Oxalate content	11	0.726
	Hand-sensed acidity score		2.977*
	Sedimentation		3.737*
Salt concentration	Oxalate content	3	0.634
	Hand-sensed acidity score		8.095**
	Sedimentation		11.333**
Time	Oxalate content	2	0.334
	Hand-sensed acidity score		0.557
	Sedimentation		1.556
Salt concentration × Time	Oxalate content	6	0.902
	Hand-sensed acidity score		1.224
	Sedimentation		0.667
Error	Oxalate content	12	
	Hand-sensed acidity score		
	Sedimentation		

*p<0.05, **p<0.01

It showed an increasing trend with salt concentration. However, the soaking time had no impact on flavour of the yam-milk mixture. Similarly, the sensory acidity score of the blend was significantly affected by the salt concentration ($p \leq 0.05$) as well as the interaction of salt concentration and soaking time.

Table RD38. Sensory colour score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	6.57±0.18	6.71±0.09	6.65±0.07	6.64
2	6.82±0.11	6.95±0.10	6.69±0.08	6.82
6	6.62±0.09	6.61±0.12	6.61±0.27	6.61
10	6.86±0.09	6.71±0.09	6.79±0.18	6.79
Mean	6.72	6.75	6.79	

Mean ± SE from 2 replicates

Table RD39. Sensory flavour score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	6.43±0.07	6.68±0.05	6.46±0.34	6.52 ^a
2	6.90±0.18	6.88±0.13	6.89±0.04	6.89 ^{ab}
6	6.78±0.10	6.81±0.10	6.81±0.09	6.80 ^{ab}
10	7.21±0.19	7.00±0.15	6.89±0.13	7.03 ^b
Mean	6.83	6.84	6.76	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD40. Sensory mouthfeel score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	6.93±0.08	6.89±0.06	6.86±0.06	6.89 ^a
2	6.44±0.24	6.40±0.23	6.85±0.17	6.56 ^b
6	6.68±0.07	6.42±0.11	6.22±0.06	6.44 ^b
10	6.36±0.14	6.29±0.04	5.72±0.09	6.12 ^c
Mean	6.60	6.50	6.41	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Although the acidity score varied from 6.97 to 7.93 and did not appreciably change up to 6% salt concentration, 10% salt resulted in a significantly higher acidity ($p \leq 0.05$) (Table RD42). The mouthfeel score of the mix was affected in a significant manner ($p \leq 0.05$) by salt concentration. It tended to follow a declining trend with increasing salt concentration.

Table RD41. Sensory acidity score[#] of EFY-milk dispersion obtained from EFY pre-soaked and cooked under different treatment combination of salt concentration and time

Salt concentration (%)	Pre-soaking time (min)			Mean
	60	90	120	
0	7.14±0.14	7.29±0.14	7.07±0.02	7.17 ^a
2	7.09±0.19	6.78±0.10	7.41±0.13	7.09 ^a
6	7.22±0.16	6.97±0.15	6.97±0.09	7.05 ^a
10	7.93±0.16	7.69±0.11	7.43±0.13	7.68 ^b
Mean	7.35	7.18	7.22	

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD42. ANOVA for changes in sensory parameters of cooked EFY (30 min boiling) paste obtained from EFY pre-soaked in acidulated saline of different salt concentrations and for varying periods

Source	Dependent variable	df	F-value
Corrected model	Colour and appearance score	11	0.750
	Flavour score		2.005
	Acridity score		5.952*
	Mouthfeel score		7.483**
Salt concentration	Colour and appearance score	3	1.742
	Flavour score		6.032*
	Acridity score		14.505*

	Mouthfeel score		17.985**
Time	Colour and appearance score	2	0.199
	Flavour score		0.323
	Acridity score		1.628*
	Mouthfeel score		2.139
Alkali concentration × Time	Colour and appearance score	6	0.439
	Flavour score		0.552
	Acridity score		3.117*
	Mouthfeel score		4.012
Error	Colour and appearance score	12	
	Flavour score		
	Acridity score		
	Mouthfeel score		

*p<0.05, **p<0.01

4.1.4 Effect of alkaline pre-soaking temperature and time on the properties of elephant foot yam

A comparison of the various pre-soaking treatments studied (vide section 4.1.1) toward mitigating the acidity/oxalate problem in the elephant foot yam, revealed alkali pre-soaking treatment to be effective in alleviating the hand sensed acidity. The three pre-soaking treatments combined with cooking, did not differ much in reducing the oxalate content.

The alkaline treatment reduced the acidity sensation to significantly ($p \leq 0.01$), while the other two combinations increased the acrid sensation significantly

($p \leq 0.05$); though significant correlation could not be observed between acidity response and reduction in the oxalate content of EFY.

The reduction from alkali treatment was observed to be concentration and time dependent. Increased alkali concentration or time decreased the acidity score of EFY paste significantly ($p \leq 0.01$). It was thought that increasing soaking temperature could potentially reduce the acidity. Huang and Hollyer (1995) reported Araceae tubers to be losing acid potency when soaked in dilute and warm alkali solutions.

Therefore, the role of alkali pre-soaking conditions including soak-solution temperature with respect to effectiveness of the treatment in reducing the dual problem of acidity and/ or oxalate was further studied employing a two-factor RSM experiment based on Central Composite Rotatable Design (CCRD). Using 0.1% NaOH solution, the effects of pre-soaking time (1-3 h) and temperature (40-50°C) on sensory acidity, Hunter colour parameters, and oxalate content were assessed.

4.1.4.1 Effects of pre-soaking time and temperature on soluble oxalate content of elephant foot yam

The water soluble oxalates exist in plants as crystals of sodium, potassium and ammonium salts (Holloway *et al.* 1989). The amount of soluble oxalate is important in food because its bioavailability is more than insoluble oxalate (Chai and Liebman, 2004). The soluble oxalate is absorbed either in proximal small intestine (Daugherty and Mrsny, 1999; Hanes *et al.* 1999; Holmes *et al.* 1995) or ileum (Hanes *et al.* 1999) and jeopardizes the human health by renal and other related implications. The soluble oxalate content of EFY paste ranged between 7.20 and 12.75 mg/100 g (Table RD43). The minimum and maximum levels were observed for the treatments 50°C/ 3 h and 38°C/ 2 h, respectively. The partial coefficients of the relevant regression model indicated that at the linear level, both pre-soaking time and temperature had a negative ($p \leq 0.01$) effect on the soluble oxalate content (Fig. RD1(a)). Thus, with the increasing level of time or temperature, the soluble oxalate content declined. The decline in soluble oxalate content could apparently have taken place via leaching in soak water (Osisiogu *et al.* 1974; Irvine, 1969; Bradbury and Holloway, 1988). The temperature could have contributed to the leaching phenomenon by softening of the EFY cubes, thereby hastening the process. Hang and Preston (2010) also observed a

reduction in oxalate content of water-soaked taro leaves after 3 h. Similarly, Iwuoha and Kalu (1995) noticed 43.3% reduction in the oxalate content of colocasia after steeping for 24 h.

The regression analysis of data revealed that the coefficient of determination (R^2) for the linear model (0.87) was high and the “lack of fit” test, which inversely measures the fitness of the model, was non-significant (Table RD44) indicating that the model is sufficiently accurate for predicting the soluble oxalate content of pre-soaked elephant foot yam with any combination of the process variables level within the range evaluated. The adequate precision was found to be 10.29, appreciably higher than the minimum desirable 4 (for high prediction ability). Further, the statistical analysis indicated that the model fitted the observed data well, the model F-value being 10.42 ($p \leq 0.01$) (Table RD44).

The soluble oxalate content could be predicted by using following linear model:

$$\text{Soluble oxalate content} = +23.09446 - 0.21405 * \text{Temperature} - 1.69852 * \text{Time}$$

4.1.4.2 Effect of pre-soaking time and temperature on the total oxalate content of elephant foot yam

Oxalic acid chelates the metal ions and exists as crystals of water insoluble salt of calcium, iron or magnesium (Noonan and Savage, 1999). Together with water soluble salts and free acid, these constitute the total oxalate content of the food material. High oxalate concentrations in the leaves and corms of plants consumed regularly are of concern because of the associated harmful health effects, especially mineral bioavailability. The total oxalate content of the yam paste ranged between 31.36 and 52.20 mg/100 g. The minimum and maximum values were observed for 50°C/ 3 h and 45°C/ 0.59 h treatments, respectively (Table RD43).

The regression analysis of data reveals that the coefficient of determination (R^2) for the quadratic model was 0.97 and the “lack of fit” of the model obtained was not significant. The adequate precision was found to be 20.04 higher than the minimum desirable 4. Further, the statistical analysis indicated that the model fitted the observed data well, the model F value being 42.75 ($p < 0.01$) (Table RD44). The negative coefficients for pre-soaking temperature ($p \leq 0.01$) and time ($p \leq 0.05$) implied that both the process variables had a negative impact on the total oxalate content of the yam ($p \leq 0.01$); however, the significant quadratic-term coefficients meant that the decrease in

the total oxalate content was non-linear and resulted in a 'convex upward' response surface (Fig. RD1(b)).

Thus, the highest temperature of the soak solution and the longest soak time led to the lowest value of the total oxalate content of EFY. Insoluble oxalates i.e calcium oxalate are hydrothermally labile (Iwuoha and Kalu, 1995). Although, the soaking temperature was relatively low, the relatively longer soaking duration might have contributed to the degradation and leaching of the oxalates by softening the tissue and causing the attenuation.

A significant depletion of oxalate has been observed upon blanching (Kim *et al.* 1993; Park *et al.* 1994; Udosen and Ukpanah, 1993) and boiling (Wanasundera and Ravindran, 1992; Iwuoha and Kalu, 1995; Bakr and Gawish, 1997; Judprasong *et al.* 2006; Akhtar, 2010), the processes which are much severe in heat intensity than the process used in present study.

The total oxalate content could be predicted by the following quadratic model:

$$\begin{aligned} \text{Total Oxalate content} = & -167.78447 + 10.23609 * \text{Temperature} \\ & + 5.04654 * \text{Time} - 0.10745 \text{Temperature} * \\ & \text{Time} - 0.11921 * \text{Temperature}^2 - 1.47108 * \text{Time}^2 \end{aligned}$$

4.1.4.3 Effect of alkaline pre-soaking conditions on sensory acidity score of elephant foot yam

The sensory acidity score of soaked elephant foot yam paste as perceived by the sensory panellists ranged between 0.00 and 0.81 (i.e. from "nil" to "slight"). The minimum and maximum levels were observed for the 45°C/ 0.59 h and 45°C/ 2 h treatment combination, respectively (Table RD43).

Neither the pre-soaking temperature nor the soak time had any significant influence on the acidity score and the model F value was found to be statistically non-significant (Table RD44).

Table RD43. Values of various responses observed after RSM experimental runs

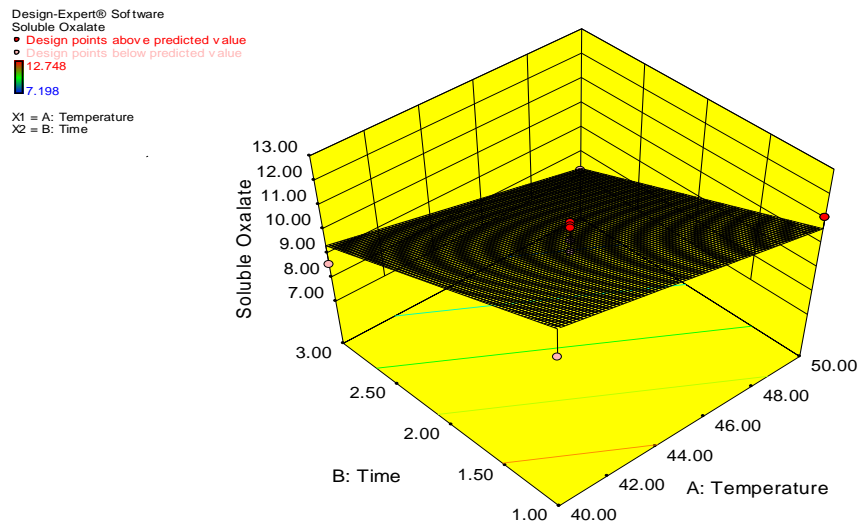
S. No.	Pre-soaking temperature (°C)	soaking time (h)	Total oxalate (mg/100 g)	Soluble oxalate (mg/100 g)	Sensory acidity score	L* value	a* value	b* value	Whiteness Index	pH	Total solids (soak water) (%)
1	50	1	43.44	11.14	0.12	45.75	18.93	23.44	37.95	9.30	1.21
2	50	3	31.36	7.20	0.15	31.52	21.97	20.00	25.35	10.15	1.42
3	45	0.59	52.20	12.46	0.00	47.42	16.52	24.48	39.69	8.86	0.53
4	37.93	2	46.39	12.75	0.22	43.76	19.67	23.02	36.13	9.80	0.79
5	45	2	45.66	9.92	0.05	39.91	20.80	21.25	32.95	9.61	1.10
6	40	1	48.79	11.73	0.38	45.04	16.12	21.85	38.70	9.48	0.81
7	52.07	2	35.45	8.12	0.17	37.23	21.68	21.50	30.20	9.69	1.32
8	45	2	46.59	10.44	0.23	39.00	21.08	21.58	31.95	9.86	1.11
9	40	3	38.86	8.63	0.07	33.98	21.65	19.88	27.73	9.84	1.24
10	45	2	44.38	10.53	0.81	38.70	20.81	22.39	31.50	9.43	1.07
11	45	2	47.74	10.67	0.34	39.08	19.84	22.29	32.16	9.49	1.25
12	45	3.41	35.67	7.83	0.12	35.19	22.51	20.87	28.29	10.13	1.56
13	45	2	45.50	9.45	0.15	37.64	20.98	22.97	30.31	9.55	1.19

Table RD44. Regression coefficients and ANOVA of fitted models for, total oxalate, soluble oxalate, acidity score, Hunter colour parameters (L*, a*, b*), whiteness Index, pH and total solids in soak water

Parameters	Total oxalate	Soluble oxalate	Acridity score	L* value	a* value	b* value	Whiteness Index	pH	Total solids of soak water
Partial Coefficients									
Intercept	45.97	10.07	0.32	38.86	20.70	22.10	31.77	9.63	1.12
Temperature (A)	-3.54**	-1.07**	-0.031 ^{NS}	-1.37 ^{NS}	0.75**	-0.057 ^{NS}	-1.44*	-3.195E-003 ^{NS}	0.17**
Time (B)	-5.67**	-1.70**	-0.014 ^{NS}	-5.32**	2.13**	-1.31**	-4.96**	0.38**	0.26**
A²	-2.98**	-	-0.047 ^{NS}	0.36 ^{NS}	-0.12 ^{NS}	-0.21 ^{NS}	0.41 ^{NS}	-	-
B²	-1.47*	-	-0.11 ^{NS}	0.76 ^{NS}	-0.70**	-5.167E-003 ^{NS}	0.82 ^{NS}	-	-
AB	-0.54 ^{NS}	-	0.085 ^{NS}	-0.79 ^{NS}	-0.62*	-0.37 ^{NS}	-0.41 ^{NS}	-	-
R²	0.9683	0.8705	0.2625 ^{NS}	0.9107	0.9709	0.6934	0.9289	0.7841	0.8339
Model F value	42.75**	33.60**	0.50 ^{NS}	14.28**	46.76**	3.17 ^{NS}	18.30**	18.16**	25.11**
Adequate Precision	20.035	16.642	1.659	12.158	20.058	5.808	13.532	12.546	14.395
Lack of Fit	NS	NS	NS	S	NS	NS	NS	NS	NS

** Highly Significant (p≤0.01); * Significant (p≤0.05), NS Non-significant (p>0.05), Significant (S)

A.



B.

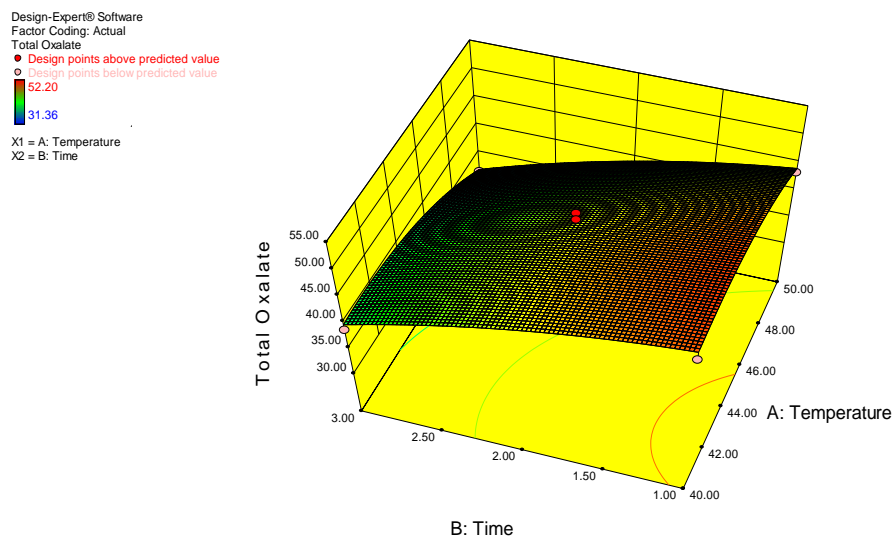


Fig. RD1. Response surface plots of (a) soluble oxalate content (mg/ 100 g) and (b) total oxalate content (mg/ 100 g) as a function of alkaline pre-soaking time (h) and temperature (°C)

4.1.4.4 Effect of pre-soaking time and temperature on Hunter color parameters and whiteness index (WI) of elephant foot yam

The pre-soaked (and cooked) yam was analyzed for its colour coordinates viz. Hunter L*, a* and b* values and whiteness index as influenced by the pre-soaking temperature and time. The model F values for all four colour parameters were significant ($p \leq 0.05$) (Table RD44) indicating that the appearance was influenced by the process variables. The coefficient of determination (R^2) were

0.83, 0.75, 0.83 and 0.82 for L^* , a^* , b^* and WI, respectively. The adequate precision for L^* , a^* , b^* and WI was 7.88, 6.32, 8.32 and 7.57, a higher than what is desired for high prediction ability. The non-significant lack of fit and significant F value for all parameters except L^* value, suggested that the respective quadratic models could be used to predict the effect of the soaking time and temperature on the colour parameters of elephant foot yam (Table RD44). The L^* value, indicating lightness of the product, varied from 31.52 to 47.42, the lowest for the 50°C/ 3 h soak and the highest for the 45°C/ 0.59 h one. However, as the lack of fit was significant, the model cannot be used to predict the effect of process variable on L value.

The Hunter a^* value (positive), which indicates the redness, varied from 16.12 to 22.51. The lowest a^* value was obtained in the product subjected to the soaking temperature-time of 40°C/ 1 h and maximum in the 45°C/ 3.41 h soaked yam. The positive linear terms ($p \leq 0.01$) suggested that increased soak temperature and time increased a^* value of the yam. Thus, both the parameters increased the redness of the product presumably due to formation of reddish-brown components as a result of the pre-soaking treatment. The negative quadratic terms ($p \leq 0.01$) implied that the increase in a^* value with increasing soaking temperature or time was curvilinear. The negative interaction between the two process variables ($p \leq 0.05$) suggested that the effect of one variable on a^* value was dependent on the level of the other, the variable being antagonistic to each other. The b^* value (positive), which indicates the yellowness, varied from 19.88 to 24.48. The lowest b^* value was obtained with temperature-time combination of 40°C/ 3 h and maximum with 45°C/ 0.59 h. The time had a negative effect ($p \leq 0.01$) on this response, as indicated by the negative linear term of the model i.e. increasing soaking time decreased the yellowness of the product. Whiteness expressed in terms of WI of the alkali-soaked varied from 25.35 to 39.69. The lowest WI was obtained with temperature-time combination of 50°C/ 3 h and highest with 45°C/ 0.59 h (Table RD43). Both the soak temperature ($p \leq 0.05$) and time ($p \leq 0.01$) had a negative influence on WI implying that with an increase in either of the process variable, whiteness decreased apparently suggesting browning or discolouration of the product. Alkaline pH has been reported to greatly enhance the non-enzymatic browning.

The whitening index could be predicted by the following quadratic model, able to explain 93% variation in the product's WI value:

$$WI = +83.67029 - 1.59396 * Temperature - 4.59465 * Time - 0.081322 * Temperature * Time + 0.016320 * Temperature^2 + 0.82314 * Time^2$$

4.1.4.5 Effect of alkaline soaking variables on the pH of EFY dispersion

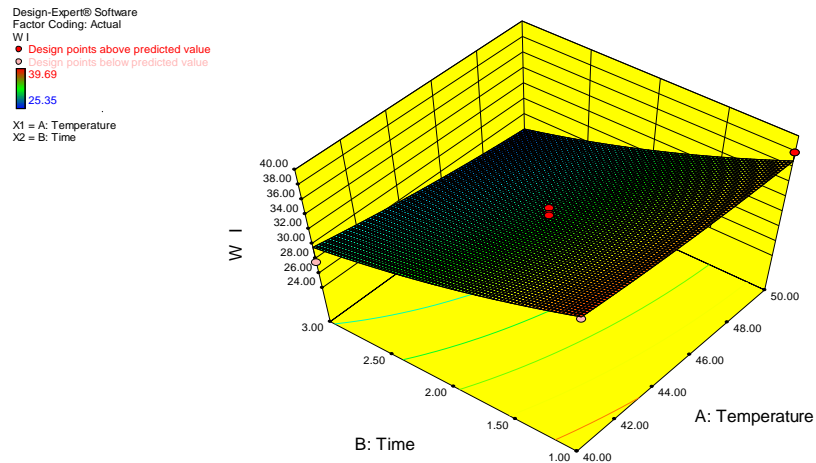
Alkali soaking of EFY could be expected to increase its pH. The pH of 10% dispersion of yam increased steadily with increased soaking time. The pH of the elephant foot yam dispersion varied from 8.86 to 10.15. The minimum pH was noticed with treatment combination of 45°C/ 0.59 h and maximum with 50°C/ 3 h (Table RD43). The model F value 18.16 was found to be highly significant ($p \leq 0.01$) and adequate precision was 10.747 higher than what is required for high predictability. The coefficient of determination was 0.78. An increased pre-soaking time increased the pH ($p \leq 0.05$) (Fig. RD(c)). The pH can be predicted by the following linear model:

$$pH = + 8.90725 - 6.39087E-004 * Temperature + 0.37576 * Time$$

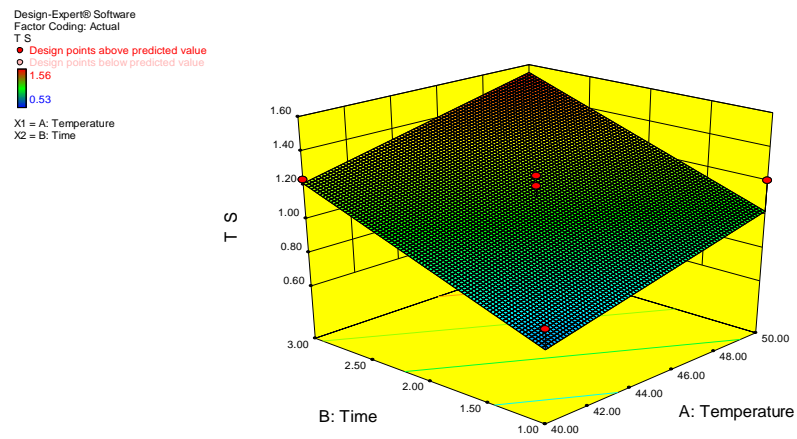
4.1.4.6 Effect of pre-soaking factors on total solids in soak water

Total solids loss is an important factor in soaking or cooking process if the product has to be consumed after draining the soak or cook water. This can lead to decreased nutritional and economical value of the food product (Guzel and Sayar, 2012) or it may increase the nutritional value by detoxifying the anti-nutritional factors present in the food system. The model F value of 25.11 was found to be significant ($p \leq 0.01$) indicating the minimal effect of noise. The adequate precision at 14.395 was sufficiently high for good predictability and coefficient of determination was 0.83. The total solid content in soak water varied from 0.53 to 1.56%. The maximum total solid loss was observed with the soak treatment of 45°C/ 3.41 h and minimum with 45°C/ 0.59 h (Table R43). Increasing alkaline soak temperature and soak time linearly increased the solids loss in the soak water ($p \leq 0.01$).

A.



B.



C.

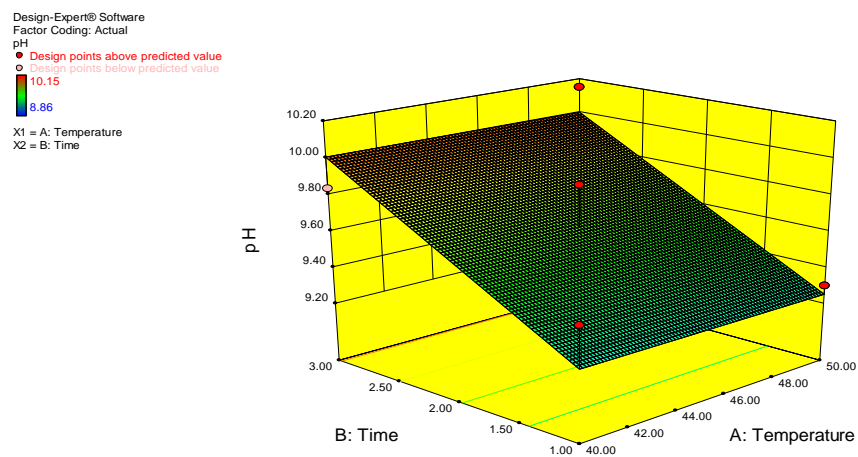


Fig. RD2. Response surface plots of (a) whiteness index, (b) total solids in soak water (TS) and (c) pH, as function of time (h) and temperature (°C)

Any increase in pre-soaking time and temperature increased the total solid loss in soak water. Increase in either of the two process variables obviously caused flaccidness and softening of the EF yam cubes which presumably contributed to increased leaching of total solids. Urga *et al.* (2006) also noticed an increase in leached solids during blanching of grass pea. The total solid loss in soak water observed in the present study could be predicted by following linear model ($R^2=0.83$):

$$TS = -0.89681 + 0.033238 * \text{Temperature} + 0.26208 * \text{Time}$$

4.1.4.7 Effect of alkali soaking on the sensory attributes of elephant foot yam

The alkali pre-soaking treatment applied to EFY certainly appeared to be an effective strategy in combating the problem of high oxalate content associated with EFY. However, the alkali pre-soaking treatment caused appreciable discoloration/ darkening of the yam as observed in terms of Hunter colour parameters, and there was no significant effect on the sensory acidity score. To further validate the adverse effects of alkali pre-soaking on the sensory status of EFY, the yam was subjected to two different sets of alkali pre-soaking conditions, which represented two extremes (60 min at 40°C and 180 min at 50°C) of the process variables. The treated yam was subjected to sensory evaluation on a semi-structured scale (0-nil to 4-extreme) for different sensory viz., darkening (colour), softness, acidity and blandness of taste. Perusal of data presented in Tables RD45 and RD 46 indicates that alkali pre-soaking significantly lowered the sensory of EFY paste.

Table RD45. ANOVA for changes in sensory responses of paste obtained from water and alkali pre-soaked EFY

Response	d.f		F value
Darkness	Between group	3	84.476**
Softness			155.00 **
Acridity	Within group	4	101.182**
Blandness			286.593**

**p<0.01

Table RD46. Sensory scores of yam paste as affected from water and alkali (NaOH) pre-soaked EFY

Treatment	Darkness	Softness	Acridity	Blandness
Control-T ₁	0.65±0.15 ^a	1.1±0.10 ^a	1.35±0.15 ^b	3.6±0.10 ^a
Treatment-1 (60 min/ 40°C)	2.7±0.20 ^b	2.3±0.20 ^b	0.45±0.05 ^a	0.7±0.10 ^b
Control-T ₂	0.95±0.05 ^a	2.2±0.10 ^b	1.25±0.05 ^b	3.65±0.15 ^a
Treatment-2 (180 min/ 50°C)	3.8±0.20 ^c	3.7±0.1 ^c	0.30±0.00 ^a	0.35±0.05 ^b

Mean ± SE from 2 replicates, means within a single column with different superscripts are significantly different as determined by Tukey's test; For control treatment, water was used as soaking medium

The alkali pre-soaked EFY was significantly darker in appearance, and softer in texture as compared to the corresponding controls. The EFY cubes subjected to treatment-1 and treatment-2 was observed to be pulpy in nature. Alkali (NaOH) soaking induced the loss of structural integrity via delignification and dissolution of hemi-cellulosic and other polysaccharide material present in the cell wall (Whistler and Miller, 1958; Jackson, 1977; Sun *et al.* 1995; Xiao *et al.* 2001)

The water soaked EFY, was perceived to be definitely acrid, nearly opposite to the alkali-soaked counterparts, in which the acridity score varied from 'nil' to 'slight'. The acridity-intensity rating of the alkali-soaked yam was observed to decline significantly ($p \leq 0.01$) from 1.35 to 0.45 (60 min at 40°C) and 1.25 to 0.30 (180 min at 50°C). These findings point out towards possibility of a reduction in acrid components via alkali soaking or the suppression of itchy/ acrid sensation by soapy nature of alkali. Any interaction occurring between acridity sensation and soapiness of alkali cannot, also be ruled out. The alkali soaking produced objectionable changes in the blandness of the EFY paste. The blandness scores for water soaked EFY were 3.60 and 3.65 while those for alkali soaked EFY the score decreased to 0.7 and 0.35 (Table RD45). The presence of disagreeable flavour affected the blandness of EFY in an adverse manner.

Thus it could possibly be concluded that soaking in sodium hydroxide solution altered sensory attributes of yam in an adverse manner. Although the acridity sensation reduced with pre-soaking treatment, but the yam obtained was sensorially rejected. The blandness, which is closely related with the edibility of

EFY, was hampered unfavourably and the yam was rejected by sensory panellists.

4.1.5 Effect of pre-soaking in NaHCO₃ solution followed by cooking of elephant foot yam upon its acidity and/ or oxalate

Of various pre-soaking treatments studied in conjunction with cooking in boiling plain water in order to reduce the oxalate content of EFY and mitigate the acidity problem associated with it, alkali soak was found promising. Hence alkali treatment at both the soaking and cooking stages was considered pertinent for further studies. Accordingly, various preliminary combinations of alkali soaking and alkali cooking (boiling) were examined.

The three treatments investigated were: soaking in 0.1% NaOH (60 min) with cooking in 0.25% NaHCO₃ (30 min); soaking in 0.5 % NaHCO₃ (60 min) with cooking in 0.25% NaHCO₃ (30 min); and soaking in 0.5% NaHCO₃ (overnight) with cooking in 0.5% NaHCO₃ (30 min) along with control (soaking in plain water (60 min) followed by cooking for 30 min). Table RD46 depicts the changes in EFY occurring as a consequence of alkali pre-soaking and alkali cooking. The EFY paste obtained from alkali pre-soaked and alkali cooked yam had an offensive odour, coupled with a mushy and pulpy texture. The structural disintegration of the yam cubes during the process of soaking and cooking caused the cubes to become soft and pulpy.

Sodium bicarbonate (NaHCO₃) has been effectively utilized for reducing the cooking time of beans and various other vegetables (Iyer *et al.* 1980; Kadam *et al.* 1981; Uzogara *et al.* 1990). Cooking in sodium hydrogen carbonate causes increased softness and increased solids loss in cook water in cow pea (Uzogara *et al.* 1988) and kidney beans (Rehman *et al.* 2001).

Table RD47 shows the Hunter colour parameters and sensory acidity score of alkali pre-soaked and cooked EFY. All treatments significantly affected ($p \leq 0.05$) the Hunter colour parameters and sensorial acidity score of the yam. Compared to control, EFY cubes subjected to alkaline soaking and cooking were darker in colour, as suggested by decreased L* value (Table RD48), apparently due to alkali-induced browning reactions. The combination of sodium bicarbonate pre-soaking and cooking tried affected the yam in manner similar to alkali soaking. The yam cubes were rejected sensorially.

Table RD47. Properties of EFY pre-soaked and cooked under alkaline conditions

Soaking and cooking treatments	Observations
Control: Soaking in plain water (60 min) + Cooking in plain water (30 min)	Most of the cubes intact, very little/ slight structural disintegration, small total solids loss, no drastic shift in colour
Treatment 1: Soaking in 0.1% NaOH (60 min) + cooking in 0.25% NaHCO ₃ (30 min)	Extensive disintegration of EFY cubes; mushiness, high solids loss in soak water, darker colour, offensive odour
Treatment 2: Soaking in 0.5 % NaHCO ₃ (60 min) + cooking in 0.25% NaHCO ₃ (30 min)	EFY cubes became pasty/ pulpy , high solids loss, colour somewhat darker; offensive odour
Treatment 3: Soaking in 0.5% NaHCO ₃ (12 hours) + cooking in 0.5% NaHCO ₃ (30 min)	Nearly the same as in-Treatment-2

Table RD48. Hunter colour values# (L*, a* and b*) and sensory acidity# score for elephant foot yam subjected to alkaline pre-soaking and cooking

Treatments	Hunter L* value	Hunter a* value	Hunter b* value	Sensory acidity score
Control	63.59±0.02 ^b	0.62±0.02 ^a	25.22±0.04 ^b	0.83±0.03 ^b
Treatment1	36.17±0.06 ^a	13.72±0.05 ^b	20.05±0.37 ^a	0.30±0.00 ^a
Treatment 2	36.58±0.01 ^a	15.66±0.03 ^c	21.01±0.06 ^a	0.20±0.00 ^a
Treatment 3	36.75±0.35 ^a	16.59±0.26 ^d	20.31±0.34 ^a	0.27±0.03 ^a

Mean ± SE from 2 replicates, means with different superscript are significantly different as determined by Tukey's test

4.1.6 Cooking of elephant foot yam in boiling water

As discussed in Sec. 4.1.1, different soaking and cooking treatments viz., alkali soaking, salt soaking and acidulated saline soaking combined with cooking in plain water to eliminate the innate acidity and oxalate problem associated with elephant foot yam, were not appreciably more effective than plain-water cooking alone; the latter contributed to substantial oxalate degradation. The alkaline treatment did offer a hint towards greater effectiveness in the oxalate reduction,

but caused considerable degradation of the sensory attributes of the yam. The sodium hydrogen carbonate treatment also had an unacceptable impact on the sensory status of the product coupled with high total solid loss in soak water and cook water, which would presumably impair the nutritional value of the product too. It thus appeared that plain-water cooking alone would suffice. Hence, further investigations were carried out with regard to the effect of the period of cooking in boiling water on oxalate content (via hydrothermal degradation) and other characteristics viz. whiteness index, phenolic content, DPPH activity along with sensory colour, acidity and softness of EFY.

4.1.6.1 Effect of boiling duration on whiteness index (derived from Hunter colour parameters L^ , a^* and b^*) of EFY paste obtained after cooking in water*

The whiteness value of EFY paste obtained after cooking in boiling water for different periods are presented in Table RD48. Cooking in boiling water did not alter the whiteness value of the EFY paste significantly (Table RD50). Thus there was no perceivable browning (enzymatic and non-enzymatic) during the plain-water boiling process. Polyphenol oxidases, the main causatives of enzymatic browning are heat labile in nature and are destroyed at 80°C (Vamos-Vigyazo, 1981). Further, non-enzymatic browning is inhibited at high water content because temperature hardly goes above boiling temperature of water. The dilution of reactants at high moisture level causes decrease in rate of non-enzymatic browning (Eichner and Karel, 1972).

4.1.6.2 Effect of boiling duration on yam solids loss in water used as the cooking medium

The total solids loss in the cooking water is an important process parameter affecting the viability of boiling in water as cooking method. It reflects the hydrothermal degradation occurring in food on cooking and thereby serves as an indicator of lethality of boiling as cooking process. The loss of solids during cooking, or even during steeping, is a normal phenomenon. This loss can lead to decreased nutritional and economic value of the food, but also can help in effacing anti-nutritional elements present in the food system. The boiling time appeared to have a significant ($p \leq 0.01$) direct effect on the solids loss occurring in cook water (Table RD49). The solids loss ranged from 0.67 to 1.95%.

Table RD49. Whiteness index[#] of EFY paste obtained after cooking in boiling water and solids loss[#] in soak water

Cooking time (min)	Solids loss (%)	Whiteness index
10	0.67±0.05 ^a	55.91±0.43
20	1.27±0.07 ^b	55.82±0.89
30	1.62±0.06 ^c	55.16±0.49
40	1.95±0.07 ^d	54.94±0.27

Mean ± SE from 4 replicates, means with different superscript are significantly different as determined by Tukey's test

Table RD50. ANOVA for changes in some physico-chemical and sensory responses of EFY paste obtained after boiling yam in water for different durations

Response	d.f		F value
Whiteness Index			0.771
Solids loss	Between groups	3	71.482**
Phenolic content	Within groups	12	149.82**
DPPH activity			29.55**
Soluble oxalate	Between groups	4	159.20**
Total oxalate	Within groups	15	733.04**
Sensory colour score	Between groups	4	17.185**
Sensory acidity score			2835.47**
Sensory softness score	Within groups	15	292.32**

**p<0.01

The increase in losses with cooking time is invariably a result of softening arising from the rise in temperature and cooking duration (Chiang and Luo, 2007). Vegetable softening during cooking is known to occur due to loss of turgor

and other complex changes occurring in cell wall matrix polysaccharides (Lewicki, 1998).

This softening, resulting from weakened cell walls and softened texture (Loh and Breene, 1982) causes loss of water and cellular solutes including polysaccharides, proteins, fraction of water soluble vitamins, minerals and other components (Femenia *et al.* 1999; Rehman *et al.* 2003; Gliszczyńska-Swigło *et al.* 2006; Xu *et al.* 2014).

4.1.6.3 Effect of boiling duration on phenolic content and anti-oxidative activity of elephant foot yam

Phenols present in nature are of much interest due to numerous roles (antioxidants, astringency, bitterness, browning reactions, color, oxidation substrates, protein constituents, etc.). These phenols are responsible for bulk of oxygen capacity in plant based foods. Free radicals (e.g., reactive oxygen and nitrogen species) generated *in vivo*, cause damage to DNA, lipids, proteins, and other biomolecules.

Phenolic and other antioxidants prevent the formation of free radicals and have been found to counter the action of free radicals *in vivo*. Folin–Ciocalteu Reagent (FCR) assay is the most preferred assay for the quantification of phenolics (Singleton, 1999). The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) free radical is considered to be a model stable lipophilic radical. In natural products, the DPPH free radical is ubiquitously used to determine potential free radical scavenging activity (Perla *et al.* 2012).

Both the FCR and DPPH assays bear good correlation and are thus used for quantification of anti-oxidative potential in terms of phenolic content and DPPH scavenging activity. The phenolic content (in terms of gallic acid) as determined by the FCR assay, declined from 7.01 mg/ g (10 min boiling) to 4.37 mg/ g (40 min boiling) and at the same time DPPH scavenging activity (in terms of trolox) dropped from 6.46 micromole TE/ g (10 min boiling) to 2.74 micromole TE / g (40 min boiling). Both the phenolics and DPPH activity showed a high degree of correlation ($r = 0.95$).

Referral to Table RD49 and Table RD50 indicates that an increased boiling time caused a significant decrease in both the anti-oxidative capacity determining parameters.

Table RD51. Total phenolic content and DPPH radical scavenging activity of EFY cooked in boiling water for different periods

Cooking treatments	Phenolic content (mg GAE@/ g EFY paste)	DPPH activity (μ mol TE/ g EFY paste)
10 min boiling	7.01 \pm 0.10 ^c	6.46 \pm 0.10 ^c
20 min boiling	5.98 \pm 0.12 ^b	5.43 \pm 0.25 ^{bc}
30 min boiling	4.74 \pm 0.06 ^a	4.35 \pm 0.42 ^b
40 min boiling	4.37 \pm 0.10 ^a	2.74 \pm 0.31 ^a
Correlation coefficient	r = 0.95 ^{**}	

Mean \pm SE from 4 replicates, means with different superscript are significantly different as determined by Tukey's test; @GAE- Gallic acid equivalent ; \$TEAC-Trolox equivalent; ** significant at 0.01 level (2 tailed)

This, in turn, points toward the loss of phytochemicals (antioxidants) during the cooking process. Leaching of phenolic antioxidant constituents in cook water upon boil-cooking, has been reported to be the main factor causing reduction in anti-oxidative parameters (Price *et al.* 1998; Vallejo *et al.* 2003; Xu and Chang, 2008).

Renard (2005) reported selective leaching of flavonoids during cooking in water. Further, boiling itself is high thermal lethality process. The breakdown of phenolics during boiling treatments may also have contributed toward the declining trend in the total phenolic content and DPPH activity (Scalzo *et al.* 2007).

The other possibilities favouring the reduction in antioxidants as a result of cooking of the yam may be chemical transformation (Cohen *et al.* 2001; Makris and Rossiter, 2001), decomposition of phenolics (Murakami *et al.*, 2004), protein-polyphenol complex formation under thermal and pressure conditions (Perla *et al.* 2012), polyphenol-polysaccharide interaction (Bernhart and Schlich, 2005), etc. Various workers have experimented upon numerous vegetables to discover cooking, boiling in particular, to be negatively impacting the anti-oxidative nature (Ismail and Lee, 2004; Roy *et al.*, 2007; Wachtel-Galor *et al.* 2008; Faller and Fialho, 2009; Perla *et al.* 2012).

4.1.6.4 Effect of boiling duration on oxalate content (soluble and total) of EFY

Oxalates (soluble and total) are considered undesirable in human. Therefore, the degradation of oxalates via cooking, for example in boiling water, is a well sought phenomenon.

Table RD52. Oxalate (total oxalate and soluble oxalate) content of EFY paste obtained after cooking in boiling water

Cooking Treatments	Soluble oxalate (mg/100 g EFY paste)	Total oxalate (mg/100 g EFY paste)
Without boiling	12.97±0.32 ^a	72.39±1.14 ^a
10 min boiling	8.38±0.16 ^b	39.99±0.38 ^b
20 min boiling	8.15±0.07 ^b	38.02±0.26 ^{bc}
30 min boiling	7.89±0.12 ^b	37.66±0.15 ^{bc}
40 min boiling	7.66±0.11 ^b	37.14±0.27 ^c

Mean ± SE from 4 replicates, means with different superscript are significantly different as determined by Tukey's test

A significant ($p \leq 0.01$) destructive effect of boiling upon oxalate level was observed (Table RD50; Table RD52). The soluble oxalate level declined from 12.97 mg/ 100 g (in raw yam) to 7.66 mg/ 100 g (40 min boiling) i.e. by 40.9%, whilst the total oxalate content (soluble and insoluble together) decreased from 72.39 mg/ 100 g to 37.14 mg/100 g (40 min boiling) i.e. by 48.7%. Table RD 52 further shows that both oxalates declined increasingly with increasing boiling duration, but the greatest reduction occurred during initial 10 min of boiling; the oxalate content in yam cooked for longer duration (20 min, 30 min and 40 min) did not differ significantly from that obtained after 10 min boiling. Thermal degradation/ decomposition at higher temperature (Sefa-Dedeh and Agyir-Sackey, 2004) and leaching of oxalates in cook water which was discarded may be considered to be the mechanism behind the observed reduction in the oxalate content of EFY. Skin rupture/ softening during boiling has been reported to facilitate the leaching process (Albihn and Savage, 2001). As mentioned in Sections 4.1.1.1.2, 4.1.1.2.2 and 4.1.1.3.2, several workers have observed significant reduction in oxalates in different foods i.e. conophor seeds (Edem *et*

al. 1994), Thai vegetables (Judprasong *et al.* 2006), Japanese taro (Catherwood *et al.* 2007), colocasia (Lewu *et al.* 2009) upon cooking boiling water.

4.1.6.5 Effect of boiling duration on sensory colour and acidity score of EFY and softness score of EFY cubes

The boil-cooked EFY were subjected to sensory evaluation (colour, acidity and softness) by a panel of judges. The sensory colour score of EFY, as judged on a 9-point hedonic scale (9 - like extremely; 1 - dislike extremely), ranged from 7.15 (40 min boiling) to 8.10 (without boiling) (Table RD52). The boiling duration had a significant effect on the colour score, the longest cooking time (40 min) leading to the lowest colour score. Intermediate boiling treatments caused a smaller decrease in the colour score, but the corresponding scores, though significantly ($p \leq 0.01$) lower than that for un-cooked yam and higher than for 40-min cooked yam, did not differ among themselves. The principal cause of the decline in colour score was darkening or browning of EFY resulting from the cooking treatment. The sensory acidity scores measured on a 5-point semi-structured scale (0 - non-acrid, 4 - highly acrid) varied from 2.12 (without boiling) to 0.10 (40 min boiling) (Table RD53). The EFY not subjected to boiling was perceived to be definitely acrid by the judges as the application of paste on the forearm caused a definite itching sensation. Cooking by boiling for 10 min or more, significantly ($p \leq 0.01$) decreased the acidity, although the decrease was slight and non-significant in the yam cooked beyond 10 min. The sensory softness score perceived by judges on 5 point semi-structured scale (0- hard to 4 very soft (pulpy)) changed significantly with boiling duration (Table RD50. With increasing cooking duration the EFY tended to become softer. The softening via boiling could be attributed to the changes in cell-wall polysaccharides and other cementing material, besides gelatinization starch, brought about by the hydro-thermal treatment. The softness score increased significantly from 0.73 (uncooked yam) to 3.72 (40 min cooking). The softening of EFY upon cooking (Table RD53) was accompanied by increased solids loss in the cooking water (Table RD49). Greater softness resulting from increased cooking time apparently contributed to an increased solids loss in cooking water, as reflected in a high correlation between these two parameters ($r= 0.96$).

Table RD53. Sensory colour, acidity and softness scores of boil-cooked EFY paste as affected by the cooking

Cooking treatment	Colour score	Acridity score	Softness score
Without boiling	8.10±0.07 ^c	2.12±0.03 ^a	0.73±0.11 ^a
10 min boiling	7.90±0.04 ^{bc}	0.16±0.01 ^b	2.37±0.06 ^b
20 min boiling	7.60±0.09 ^b	0.12±0.01 ^b	2.67±0.05 ^c
30 min boiling	7.55±0.09 ^b	0.10±0.01 ^b	3.22±0.05 ^d
40 min boiling	7.15±0.13 ^a	0.10±0.01 ^b	3.72±0.04 ^e

Mean ± SE from 4 replicates, means with different superscript are significantly different as determined by Tukey's test; colour score measured on 9 point Hedonic scale; Acridity and softness score measured on 5 point semi-structured scale

It thus appeared that cooking of EFY for different durations caused considerable changes in the various phytochemicals present in it. The effect of cooking was also significant the sensory attributes of cooked EFY paste (colour and acidity) and cubes (softness). Further, as noted in sections 4.1.4.4 and 4.1.4.5, boil-cooking of the yam significantly decreased the oxalate content, both soluble and insoluble. Boiling for 10 min caused 35.39% reduction in soluble oxalates and 44.76% in total oxalates. However, boiling for more than 10 min did not cause significantly greater destruction of oxalates. Similar trends were noticed in the cooking-mediated reduction in sensorial acidity score. Accordingly, 10 min cooking as such was considered to be sufficient for reduction of oxalates. Hence, 10 min boiling was resorted to for cooking elephant foot yam in further studies.

4.1.7 Drying of cooked elephant foot yam

The pre-treated and pre-cooked EFY was proposed to be converted into a powder form so as to make it shelf stable and enable its appropriate use as an ingredient for various dairy (and other) foods. Accordingly, 10-minutes boil-cooked yam was used for drying into a powder. Various drying options were examined and the results are discussed in the following paragraph

4.1.7.1 Drum drying of cooked elephant foot yam

Drum drying is next only to spray drying among the most practised drying methods. It is particularly effective for drying high viscous liquid or pureed foods. Nowadays, drum dryers are used in the food industry for drying a variety of

products, such as milk protein products, baby foods, breakfast cereals, fruit and vegetable pulps, mashed potatoes, cooked starch, and spent yeast (Rodriguez *et al.* 1996). To obtain large quantities of EFY powder, drum drying of cooked EFY slurry was carried out using a counter-rotating twin drum dryer (P210, NTN Corporation Ltd., Canada).

Table RD54. Effect of total solids in EFY-water slurry on drum drying

Total solids in EFY-water slurry (%)	Drying performance
7.55	Poor flowability, no film formation on drums
6.70	Flowability/fluidity improved, but poor film formation
5.50	Partial drying, lumps formation
4.50 - 5.00	Same as above

The cooked yam-milk dispersion and cooked yam-water slurry were dried at different total solids levels. The initial slurry containing about 20% solids (similar to milk concentrate in total solids, but higher in viscosity), was very thick and its high consistency restricted its flow from the balance tank to the dryer. To increase the fluidity the slurry was diluted with milk or water. The drying of the slurry was, however, not feasible because of lack of film forming ability of the slurry (Tables RD54 & RD55).

The film formation is deemed necessary for effective drum drying operation (Vallous *et al.* 2002; Gavrielidou *et al.* 2002). The incomplete or partial drying led to lump formation rather than yielding a free-flowing powder. Further, it was not possible to manipulate the drum speed (20 rpm) so as to get the desired film formation. The drum rotation speed is an important factor affecting the performance of a double-drum dryer (Kostoglou and Karapantsios, 2003).

Nevertheless, drum drying could be a good option for obtaining powder if technical considerations are taken well. In the operation of drum dryer, a delicate balance needs to be established among feed rate, steam pressure, roll speed, and thickness of the product film. Being an HTST operation, drum drying is recommended as valuable nutrients are not lost (Tang *et al.* 2003).

Table RD55. Effect of total solids in EFY-milk slurry on drum drying

Total solids level in EFY-milk slurry (%)	Drying observations
13.10	Limited flowability of slurry, no film formation, poor drying
6.00	Flowable, partial film formation resulting in product lumps.

4.1.7.2 Spray drying of cooked elephant foot yam

The spray drying of cooked EFY slurry was also attempted using a nozzle-atomizer, co-current spray dryer (SSP Ltd., Faridabad). The total solids content of the homogenized slurry was 5-15%. However, blockage of atomizer nozzle and excessive sticking of the process material on the walls of the spray drier made it impossible to obtain a satisfactory yam powder. Hence spray drying had also to be abandoned.

4.1.7.3 Tray drying of cooked elephant foot yam

Since the drum-drying and spray-drying processes were found unworkable. Tray drying, even though a time-taking drying process was resorted to, for drying of cooked EFY paste. Hot air drying of food spread in trays is one of the most frequently used operations for food dehydration. It is still the most popular method applied to reduce moisture content of fruits and vegetables (Lewicki, 2006; Leonid *et al.* 2006) and extend their shelf life. In addition to preservation by removal of moisture and decreasing the water activity, drying simultaneously causes reduction in the cost or difficulty of packaging, handling, storage, and transport by converting raw food into a dry form (Orikasa *et al.* 2014). The dehydration process also induces number of physicochemical changes that are usually time-temperature dependent. The hot-air drying was carried out at different temperatures (50°C, 60°C and 70°C) till the yam paste acquired a brittle consistency (Njintang and Mbofung, 2006). The final moisture content varied for dried products. The powder obtained after drying at 50°C, 60°C and 70°C had a moisture content of 6.8%, 6.4% and 4.5%, respectively. As could be expected, the drying time decreased with increasing temperature. The EFY paste (~510 g) took least time (~270 min) for drying at 70°C, while the time taken at 50°C was recorded to be around 780 min, and that at 60°C 495 min.

4.1.7.3.1 Physical properties of yam powder viz. whiteness index (WI), browning index (BI), bulk density (BD), true density (TD) and porosity as influenced by tray drying temperature

It can be seen from Table RD56 that the colour of the dried yam was influenced in a significant manner by the drying temperature. The whiteness index varied from 66.33 (70°C) to 71.15 (50°C).

Table RD56. Whiteness index[#] and browning index[#] of tray dried elephant foot yam

Drying Temperature	Whiteness index	Browning Index
50°C	71.15±0.06 ^c	0.28±0.01 ^a
60°C	69.05±0.35 ^b	0.31±0.00 ^b
70°C	66.33±0.42 ^a	0.37±0.01 ^c
F ratio	56.958 ^{**}	58.965 ^{**}
Correlation coefficient (r)	-0.928 [@]	

Mean ± SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; @ significant at 0.01 level (2- tailed); **p<0.01

The whiteness index, which is derived from Hunter colour parameters (L*, a* and b*), and gives the cumulative representation of all three colour parameters, showed a gradual and significant decline (p ≤ 0.01) (i.e. whiteness of the powder decreased) with increasing drying temperature. This is attributed to the formation of brown and other coloured substances via the process of non-enzymatic browning during drying. The WI bears a direct correlation with Hunter L* value and indirect relationship with Hunter a* and Hunter b* values. The drying treatment have been reported to negatively impact the Hunter L value (Ortiz *et al.* 2013), which is a measure of lightness of the product. The Browning Index (BI) measured as the absorbance of ethanol extract at 420 nm, ranged from 0.28 (50°C) to 0.37 (70°C). The BI, as the name itself suggests, measures the discoloration of the product. It increased significantly (p ≤ 0.01) as the temperature of drying air was increased, the inverse correlation between the two being highly significant. Increased drying temperature was reported to cause an increase in formation of non-enzymatic browning related compounds (Miranda *et al.* 2009).

Akissoe *et al.* (2003) observed 'brown index', similar to the BI, used for monitoring browning in *Dioscorea rotundata*, to be increasing significantly during drying. Non-enzymatic browning reactions occur during drying and increasing temperature further speeds up the discoloration. The reaction of free sugars produced via starch hydrolysis during cooking, with free amino acids presumably gave rise to brown discoloration (Njintang and Mbofung, 2003) via Maillard browning. Another reason actuating the browning could probably be dextrinization. The dry heat treatment is known to cause breakdown of starch into smaller subunits, and subsequent formation of brown coloured intermediates known as pyro-dextrins which might have further darkened the colour of the product by inducing browning. Various authors have reported browning to be causing discoloration in various foods i.e. aloe vera (Femenia *et al.*, 2003), carrots (Koca *et al.* 2007), durian chips (Jamradloedluk *et al.* 2007), red pepper (Vega-Galvez *et al.* 2008) during drying.

Bulk density is the mass of particles in a unit volume of the product. This measurement accounts for the void spaces between the particles and acts as an indicator of material/ product compaction. The void space in the food material is expressed as porosity, which is measured as the volume not occupied by the solid material. Particle density takes into account the presence of internal pores in the food particles. This density is defined as the ratio of the actual mass of a particle to its actual volume. The knowledge of these basic properties is helpful in designing and control of various processes. The densities were determined by volume displacement method. The bulk density varied from 0.69 g/ cm³ (50°C) to 0.73 g/ cm³ (60°C), while true density ranged from 1.49 g/ cm³ (60°C) to 1.53 g/ cm³ (50°C). Porosity value for yam flour was calculated to be 0.51-0.55. The bulk density showed a significant ($p \leq 0.05$) increasing trend with increasing drying temperature (Table RD 57).

The powder obtained after drying at higher temperatures was observed to be more compact, as indicted by increased bulk density values. Njintang and Mbofung (2006) also observed an increase in bulk density value with drying temperatures. Cooked powder is said to have higher bulk density than raw powder, because the starch gelatinization during cooking, bestows the powder with a dense and compact structure.

Table RD57. Bulk density[#], true density[#] and porosity[#] of tray dried elephant foot yam

Drying Temperature	Bulk Density (g/cm ³)	True Density (g/cm ³)	Porosity
50°C	0.69±0.01 ^a	1.53±0.01	0.55±0.00 ^b
60°C	0.73±0.01 ^b	1.49±0.02	0.51±0.01 ^{ab}
70°C	0.72±0.01 ^{ab}	1.52±0.02	0.53±0.01 ^a
F ratio	7.462 [*]	1.2570	5.067

Mean ± SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * p<0.05, **p<0.01

The increase in bulk density may be linked to gelatinization presumably occurring in, initial stages of drying when moisture content is high. Hsu *et al.* (2003) reported higher bulk density of *Dioscorea* flour upon hot air drying than both freeze and drum drying. Higher bulk densities are beneficial if powder is to be used as thickener (Kaushal *et al.* 2012).

The true density was not significantly affected by the drying temperature. Koc and Eren (2008) reported substance density to be unaffected by drying treatments i.e hot air drying at 70°C, infrared-drying at 70°C, freeze drying and osmotic dehydration(40°C -tray drying(70°C) combined. Porosity values were consistent with bulk density values; the powder obtained at the lower temperature showed significantly (p ≤ 0.05) higher porosity. Similar observation was also made by Ramakumar (2011). The true density was higher and porosity lower in yam powder obtained by hot air drying, when compared to powders obtained by freeze- and drum-drying processes.

4.1.7.3.2 Physical functional properties of yam powder viz. water absorption index (WAI), water solubility index (WSI), oil absorption index (OAI) and pasting characteristics as influenced by tray drying temperature

Water absorption index (WAI) is an important functional attribute for any food powder. In the context of yam powder, it can be used as an index of starch gelatinization, since native starch does not absorb water at room temperature (Lazou and Krokida, 2010). It measures the volume occupied by the starch or starchy food after swelling in excess water and indicates the integrity of starch in aqueous dispersion (Ahmed *et al.* 2010). WAI of EFY powder was significantly

affected by drying temperature ($p \leq 0.05$) and varied from 4.78 (50°C) to 5.06 (70°C) (Table RD58).

Table RD58. Water absorption index[#], water solubility index[#] and oil absorption index[#] of tray dried elephant foot yam

Drying Temperature	Water absorption index	Water solubility index	Oil absorption index
50°C	4.78±0.08 ^a	30.05±0.87 ^b	1.39±0.01 ^b
60°C	4.84±0.06 ^{ab}	23.85±0.66 ^a	1.35±0.01 ^{ab}
70°C	5.06±0.03 ^b	23.47±0.21 ^a	1.34±0.01 ^a
F ratio	6.415*	33.266**	6.771*

Mean ± SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * $p < 0.05$, ** $p < 0.01$

The increased drying temperature led to increased WAI of the powder. The higher degree of starch gelatinization during drying/ heating process was presumably the main cause of the higher water absorption (Hsu *et al.*, 2003). Increased temperature of drying possibly caused increased disruption in starch granule structure and thus made them absorb more water. Starch granules when heated in water undergo gelatinization accompanied by disruption of molecular order which leads to the loss of crystallinity and increase in ability to absorb water (Bemiller and Whistler, 1997). An increase in extrusion temperature was reported to cause increase the WAI of various extrudates (Gujska and Khan, 1990; Ilo *et al.* 1996; Singh *et al.* 2007).

Water solubility index (WSI) reflects the extent of starch degradation (Diosady *et al.* 1985). This index is often used as an indicator for the degradation of molecular compounds (Kirby *et al.* 1988) and particularly measures the amount of solubles released from the starch granules after the thermal treatment. The WSI of EFY powder decreased significantly with increasing drying temperature ($p \leq 0.01$). The highest value i.e. 30.05 was recorded for EFY dried at 50°C while the least i.e. 23.47 was observed for the one dried at 70°C. Similar effect of drying temperatures have been reported for cowpea (Karanja *et al.* 1996), common bean (Njintang *et al.* 2001), taro (Njintang and Mbofung, 2006) etc.

Contrary to this, a rise in temperature has been stated to cause an increase in the WSI of extruded rice-legume blends (Chauhan and Bains, 1988), rice flour (Kadan *et al.* 2003), wheat based snacks (Ding *et al.* 2006), pea grits

(Singh *et al.* 2007). The decrease in WSI with increasing drying temperature suggests that less degradation of starch occurred at higher temperatures. This could possibly be due to the shortened drying time at higher temperatures. The EFY paste dried at 50°C took longer time (780 min vs. 270 min) for drying and showed higher WSI. Thus, drying time appeared to be as important as temperature, in influencing the WSI.

Oil absorption index (OAI), the ability of the powder to bind oil is an important functional attribute with respect to several potential food applications of the yam powder. The ability to bind fat is known to improve the flavour retention and improve palatability (Kinsella, 1980). The oil absorption may be due to physical entrapment (capillary interaction) (Munea *et al.* 2014) or some hitherto unexplained interaction of oil with powder components, particularly starch, fibre and protein (Narayan and Rao, 1982; Aguilera *et al.* 2011).

The OAI showed a significant declining ($p \leq 0.05$) trend with increasing drying temperature. The OAI decreased from 1.39 (50°C) to 1.34 (70°C), Table RD58). As against this, many workers have reported OAI to increase with temperature (Gujska and Khan, 1990; Lazou and Krokida, 2010). Temperature-dependent changes occurring in starch (dextrinization/ gelatinization), fibre (degradation) or protein (denaturation, change in surface hydrophobicity) (Kinsella, 1976; Gujska and Khan, 1991; Kadan *et al.* 2003) during drying might have adversely affected the lipid binding ability and led to decrease in OAI. Decrease in OAI was also observed by Aguilera *et al.* (2011) as result of drying in bean flour.

Pasting is the phenomenon following gelatinization in the dissolution of starches. It involves granular swelling, exudation of the granular molecular components, and eventually, total disruption of the granules (Atwell *et al.* 1988). Table RD59 depicts the pasting properties of elephant foot yam powder obtained after tray drying at different temperatures (50°C, 60°C and 70°C).

Peak viscosity indicates the water binding capacity of the starch. It is often correlated with product quality with respect to its thickening ability and also provides an indication of viscous load likely to be encountered by the mixing cooker. Peak viscosity occurs at the equilibrium point between swelling and polymer leaching. It is the highest viscosity attained irrespective of the temperature (Biliaderis, 2009). The peak viscosity decreased significantly with

increasing drying temperature ($p \leq 0.01$). The powder obtained upon drying at 50°C showed the highest peak viscosity (752 mPa.s) while the one dried at 70°C showed the least peak viscosity (467 mPa.s). The results imply that a higher drying temperature, having caused more extensive gelatinization of starch in the product, caused a greater breakdown of swollen starch granules which resulted in lower peak viscosity during the RVA run. Only intact swollen starch granules are known to give rise to paste viscosity (Liu, 2005). Malumba *et al.* (2010), Ramakumar (2011) and Pancha-arnon and Uttapap (2013) also observed a corresponding decrease in the peak viscosity of heat-moisture treated corn starch, elephant foot yam powder and rice starch, respectively, with increasing drying temperature. The hot air drying is more conducive to starch breakdown by the amyolytic process which is believed to cause reduction in viscosity (Yadav *et al.* 2006).

Table RD59. Pasting characteristics[#] of tray dried elephant foot yam

Drying Temperature	PV (mPa.s)	TV (mPa.s)	B (mPa.s)	FV (mPa.s)	SV (mPa.s)	PT (°C)
50°C	752.00 ±6.25 ^a	663.00 ±4.93 ^a	89.00 ±1.53 ^a	1095.33 ±3.38 ^a	432.33 ±2.40 ^a	87.88 ±1.66 ^a
60°C	548.00 ±6.11 ^b	468.00 ±4.36 ^b	80.00 ±2.08 ^b	848.00 ±6.08 ^b	380.00 ±2.00 ^b	94.09 ±1.02 ^b
70°C	466.67 ±5.78 ^c	387.67 ±4.81 ^c	79.00 ±1.53 ^b	768.67 ±5.55 ^c	381.00 ±1.00 ^b	94.32 ±0.34 ^b
F ratio	590.49 ^{**}	905.17 ^{**}	10.11 [*]	1099.30 ^{**}	249.35 ^{**}	10.22 [*]

Mean ± SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * $p < 0.05$, ** $p < 0.01$; PV-peak viscosity; TV-trough viscosity; B-breakdown viscosity; FV- Final viscosity; SV-setback viscosity; PT-pasting temperature

During the holding period of RVA test, the starch gel in the sample canister is subjected to high temperature and shear via the rotating paddle, which causes disruption of starch granules and leaching out of the amylose. This period is commonly associated with decrease in the viscosity which is referred to as holding strength/ hot paste viscosity or 'trough viscosity'. The difference between peak viscosity and trough viscosity is termed as breakdown. Both these viscosities figure out the ability of the material to withstand heat and shear. The trough viscosity varied from 388 mPa.s to 663 mPa.s whilst the breakdown

ranged from 79 mPa.s to 89 mPa.s. Both these parameters were significantly altered by the drying temperature. Higher values were obtained at lower temperatures and vice-versa. High value of breakdown is usually associated with high peak viscosity, which relates to the degree of swelling of starch granules during heating (Ragaei *et al.* 2006). It indicates that the material has undergone a high swelling and subsequent disintegration (Abera and Rakshit, 2003). The decreased value of breakdown at higher temperature indicates the stability of paste of powder obtained by drying at higher temperature. Decrease in breakdown viscosity was non-significant for powder obtained during drying at 60 and 70 °C.

Following the holding period, the mixture is cooled in accordance with the time-temperature program. This cooling causes starch molecules, especially amylose, to re-associate and re-order among themselves and the phenomenon is called 'retrogradation', in which the molecule re-association causes viscosity to rise and a gel to form. The viscosity at end of the RVA run is termed as 'final viscosity' and the difference between trough and final viscosity is known as 'setback'. Thus the setback involves retrogradation (Eliasson and Gudmundsson, 1996). Final viscosity is valuable in defining the ability of material to form gel after cooking and cooling while setback is associated with texture loss (weeping) of various products. The final viscosity values were 1095 mPas, 848 mPas and 768 mPas for powder obtained by drying EFY at 50°C, 60°C and 70°C; the corresponding setback values were 432 mPas, 381 mPas and 380 mPas. Thus the final viscosity was significantly affected by drying temperature ($p \leq 0.01$) and so was the setback viscosity. A significant decline was observed in the final viscosity values of powder obtained by drying at higher temperatures; the highest value being recorded at the lowest temperature and vice versa.

Setback viscosity also subsided as the drying temperature increased from 50°C to 60°C ($p \leq 0.01$), but no significant difference could be observed between setback viscosity of powders obtained at drying temperatures of 60°C and 70°C. In food products based on starch gels, retrogradation causes liquid to ooze out from the gel. The phenomenon, known as syneresis or weeping, is generally undesirable. High setback is associated with syneresis during freeze-thaw treatment of a starchy food and a lower setback value indicates a lower extent of starch retrogradation and consequently less syneresis. The powder obtained

upon drying at 60°C or 70°C could therefore be considered more freeze-thaw stable, as indicated by its low setback viscosity and thus possessed greater ability than its counterparts to avoid weeping during freezing/ thawing operations. The rate at which viscosity increases in yam starches during cooling is dependent on the degree of starch-water binding (Ayernor, 1985). Therefore, the powder obtained after drying at higher temperature apparently had significantly less starch-water binding ability.

Another crucial pasting parameter determined by the rapid visco-amylography is pasting temperature. When the temperature reaches the gelatinization temperature, starch granules begin to swell, and viscosity increases. The temperature at the onset of this rise in viscosity is called as 'pasting temperature'. The pasting temperature suggests the minimum temperature required to cook the given sample. The pasting temperature was altered in a significant manner ($p \leq 0.05$) by the drying temperature and it showed tendency to increase with rising drying temperature. The pasting temperature of yam powders ranged from 87.88-94.32°C.

The pasting characteristics of cooked and dried powder as determined by RVA analysis were considerably affected by drying at different temperatures. All viscosity values showed a declining inclination with rising drying temperature while an increasing trend was observed for pasting temperature.

Watcharatewinkul *et al.* (2009) observed decrease in peak viscosity, final viscosity, break down and setback viscosity along with increase in pasting temperature of canna starch treated with heat in the presence of water. If an analogy is drawn with pasting property of heat moisture treated starch, it could be well noticed that cooking with drying aided in strengthening of the starch present in EFY powder by structural re-arrangements (Hoover and Vasanthan, 1994) which might have increased crystallinity. Due to increased crystallinity granules require more heat before structural disintegration and paste formation which presumably resulted in increased pasting temperature and limited starch swelling (Lawal, 2005). Various workers reported reduction in viscosity values following heat-moisture treatment of normal maize, amylo maize (Hoover and Manuel, 1996), potato (Kulp and Lorenz, 1981), oat, lentil and yam starches (Hoover and Vasanthan, 1994).

4.1.7.3.3 Effect of the tray drying temperature on the phytochemical content (soluble and total oxalate, phenolic content and antioxidant activity) of the yam powder

As discussed in the foregoing sections, the presence of oxalates in roots, especially those belonging to Araceae (Aroid) family has been associated with acidity or toxicity. Therefore, the oxalate content in elephant foot yam, or for that matter, any Araceae food becomes important in the assessment of its nutritional status. Table RD60 shows that the oxalate (soluble and total) level of EFY was not significantly affected by the drying temperature.

Soluble oxalate content of EFY ranged from 27.02 mg/ 100 g to 28.05 mg/ 100 g, the drying temperature showing no significant difference. A similar trend was observed for total oxalate content which varied from 199.00 mg/100 g to 202.13 mg/ 100 g. The marginal differences in the oxalate contents of the yam powder may be attributed to the variation in the moisture content of the product obtained at different drying temperatures.

Table RD60. Soluble oxalate content[#] and total oxalate content[#] of tray dried elephant foot yam

Drying temperature	Soluble oxalate (mg/ 100 g)	Total oxalate (mg/ 100 g)
50°C	27.02±1.40	200.16±4.08
60°C	27.04±1.26	199.00±3.83
70°C	28.05±0.82	202.13±3.30
F ratio	0.788 ^{NS}	0.841 ^{NS}

Mean ± SE from 3 replicates; means with different alphabetic superscript in same columns are significantly different as determined by Tukey's test; * p<0.05, **p<0.01; NS - Non-significant

The results appeared to be in contrast with earlier studies which reported oxalates to decline with drying temperature (Brown, 1995; Sundaresan and Nambisan, 2008; Hang and Preston, 2010), the main cause of decline being thermal decomposition of oxalates during hot air drying. High temperatures are known to cause the calcium oxalate-containing cells (raphides) to collapse, leading to the breakdown of oxalate structure. The non-effectiveness of the drying treatment regarding reduction in the oxalate content observed in the present study may be linked to the relatively low drying temperatures. Sefa-

Dedeh and Agyir-Sackey (2004) observed sun drying or oven drying of *Colocasia esculenta* to be ineffective in causing reduction of oxalates.

Phenolics and poly-phenolics are among the most desirable food bio-actives because of their antioxidant activity. These polyphenols render beneficial effects on human health. Therefore, the quantification of phenolic content as well as antioxidant activity was carried out on the EFY powder to gauge the full nutritional/ health potential of the food. Phenolic content of the alcohol (methanol) and water-extracts of yam powder obtained by drying at different temperatures was determined using Folin-Ciocalteu reagent.

The phenolic content, was extracted both in methanol and water, and expressed as μg GAE (gallic acid equivalent) per gram powder. The water extract was found to contain higher amount of polyphenols than the methanolic extract. Presumably, EFY powder contained more water soluble (polar) phenolics than alcohol-soluble ones. Table RD61 further shows that the phenolic content of the methanolic extract of EFY powder decreased from 0.41 to 0.36 μg GAE/ g ($p \leq 0.05$), and that of the aqueous extract from 1.68 to 1.45 μg GAE/ g as the drying temperature increased significantly ($p \leq 0.01$) from 50° to 70°C.

The recovery of polyphenols from food material depends upon solubility characteristics of the phenolic compounds in the solvent used for the extraction process. In this regard, polarity of extracting medium plays a crucial role in extraction process (Nazck and Shahidi, 2006). Therefore, no single extraction procedure is able to quantify the full phenolic potential of any food material. Mostly ethanol and water are used as extraction systems for quantification of polyphenols in plant materials (Bahorun *et al.* 2004; Durling *et al.* 2007), because of the ability of these solvents to dissolve wide range of phenols and better acceptability among human consumption models (Allothman *et al.* 2009). Other extraction solvents used include methanol, acetone, propanol, ethyl acetate, diethylformide, formic acid (Luthria and Mukhopadhyay, 2006; Santas *et al.* 2008; Belviso *et al.* 2013; Lou *et al.* 2014; Alberti *et al.* 2014). The phenolics content, in both types of the extract showed a significant ($p \leq 0.01$) declining behaviour with increased drying temperature probably because of thermal degradation during drying (Vega-Galvez *et al.* 2012).

Table RD61. Phenolic content[#] present in tray dried elephant foot yam

Drying Temperature	Phenolic content (($\mu\text{g GA/ g powder}$)	
	Water extract	Methanolic extract
50°C	1.68 \pm 0.01 ^c	0.41 \pm 0.01 ^b
60°C	1.59 \pm 0.01 ^b	0.40 \pm 0.00 ^{ab}
70°C	1.45 \pm 0.02 ^a	0.36 \pm 0.01 ^a
F ratio	47.457 ^{**}	9.331 [*]

Mean \pm SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * p<0.05, **p<0.01; GA- gallic acid

Table RD62. DPPH scavenging activity[#] of tray dried elephant foot yam

Drying Temperature	DPPH Scavenging Activity ($\mu\text{mol TE/ g powder}$)	
	Water extract	Methanolic extract
50°C	1.38 \pm 0.04 ^c	0.24 \pm 0.01 ^a
60°C	1.17 \pm 0.04 ^b	0.27 \pm 0.01 ^{ab}
70°C	0.98 \pm 0.05 ^a	0.29 \pm 0.01 ^b
F ratio	16.989 ^{**}	13.046 ^{**}

Mean \pm SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * p<0.05, **p<0.01; TE-trolox equivalent

Table RD63. ABTS activity[#] of tray dried elephant foot yam

Drying Temperature	ABTS Activity ($\mu\text{mol TE/ g powder}$)	
	Water extract	Methanolic extract
50°C	2.80 \pm 0.02 ^b	0.84 \pm 0.03 ^a
60°C	2.69 \pm 0.04 ^b	0.84 \pm 0.02 ^a
70°C	2.50 \pm 0.05 ^a	1.01 \pm 0.04 ^b
F ratio	23.671 ^{**}	11.906 ^{**}

Mean \pm SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * p<0.05, **p<0.01

Decrease in total phenolic content with increasing drying temperature has been reported by other workers (Kyi *et al.* 2005; Ahmed *et al.* 2010; Khanal *et al.* 2010; Martinez-Heras *et al.* 2014).

The decrease in the phenolics content during drying may also be attributed to various other factors such as interaction of phenols with other constituents (protein), modification in chemical structure of polyphenols, conformational

changes and difficulty in extraction, thermal breakdown of polyphenols etc. (Davey *et al.* 2002; Li *et al.* 2006; Martin-Cabrejas *et al.* 2009; Qu *et al.* 2010).

The antioxidant activity as determined by DPPH and ABTS assays, showed a unique pattern of change associated with the drying temperature. Both assays revealed the antioxidant activity of water extract to decrease with rising drying temperature. For the water extract, the DPPH activity decreased from 1.38 to 0.98 $\mu\text{mol TE/g}$ powder and ABTS activity declined from 2.80 to 2.50 $\mu\text{mol TE/g}$. However, the methanol extract showed, in both the assays, significantly ($p \leq 0.01$) increasing antioxidant activity with increasing drying temperature.

The antioxidant activity of water extract showed good correlation with the phenolic content of the water extract; as the phenols decreased, the anti-oxidative potential of the powder also decreased. But decrease in the phenolics of methanol extract appeared to be in disagreement with the observed antioxidant activity; both the assays displayed a significant increase ($p \leq 0.01$) in the anti-oxidative capacity of the methanolic extract, even though its phenolics content decreased due to high heat treatment.

The DPPH activity increased from 0.24 to 0.29 $\mu\text{mol TE/g}$ and ABTS activity increased from 0.84 to 1.01 $\mu\text{mol TE/g}$. This apparently points to certain other, non-phenolic compounds contributing to the antioxidant potential of the alcoholic extract. The antioxidant activity, as measured by both anti-oxidative assays, was observed to be in agreement with the browning index (BI). Lopez *et al.* (2010) reported increased anti-oxidative activity with increased browning reactions at higher drying temperatures.

Non-enzymatic browning reactions, particularly Maillard browning, are linked to the formation of compounds with strong antioxidant capacity. The high antioxidant capacity is attributed not only to formation of brown coloured melanoidins (Anese *et al.* 1994; Yen and Hsieh, 1995), but also to various intermediate compounds, generally referred to as Maillard reaction products (MRPs) i.e amino reductones, heterocyclic amines (Dttrich *et al.* 2009) generated during the Maillard browning process. The MRPs possess a hydrogen donating ability, which suggests their potency to react with free radicals (Wang *et al.* 2013).

4.1.7.3.4 Influence of drying temperature on sensory attributes (flavour and mouth-feel) of yam-milk dispersion prepared from elephant foot yam powder

In order to assess the compatibility of yam powders obtained by tray drying at different temperatures, the yam powder was incorporated in milk (Fat-3%, SNF-9%) @ 2%. Subsequently, pasteurized and cooled yam-milk dispersion was evaluated for its flavour and mouth-feel on a 10 cm semi-structured linear (intensity-rating) scale (0-100). The data presented in Table RD64 show that the flavour ($p \leq 0.01$) and mouth-feel ($p \leq 0.05$) scores of the yam-milk dispersion significantly increased as the drying temperature was increased from 50° to 60°C.

Table RD64. Flavour and mouth-feel scores[#] of yam-milk mix tray dried elephant foot yam

Drying Temperature	Flavour score	Mouth-feel score
50°C	63.33±0.33 ^a	53.33±1.21 ^a
60°C	74.33±1.21 ^b	59.67±0.88 ^b
70°C	74.00±1.00 ^b	60.33±0.88 ^b
F ratio	45.957 ^{**}	14.926 [*]

Mean ± SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * $p < 0.05$, ** $p < 0.01$

However, further increase in the drying temperature to 70°C did not result in any significant increase in the sensory scores. The flavour score varied from 63.3 to 75.0; the lowest flavour score was obtained for powder obtained after drying at 50°C. The mouth-feel score increased from 53.3 to 60.3.

Thus, the flavor and mouth-feel scores of yam-milk mix were maximum for the yam powder obtained upon drying at 60°C. Therefore this drying temperature was deemed optimum for making yam powder meant for incorporation into milk to be processed into other dairy products. Also, the powder obtained at 60°C, had the lowest setback viscosity (380 mPa.s). The setback value, associated with retrogradation of starch molecules, tends to affect the texture of the food product. High setback value is associated with syneresis during the refrigeration, and therefore is not desirable in products such as yoghurt or *dahi*.

4.2 PROPERTIES OF DAHI and LASSI BLENDED WITH ELEPHANT FOOT YAM

Fermented foods are of great significance, since they provide and preserve vast quantities of nutritious foods in wide varieties of flavors, aromas

and textures. Fermented foods are an excellent medium to generate an array of products that fit into the consumer demand for health based foods. Consumption of fermented milks has increased significantly around the world and nowadays various popular ingredients of functional significance are being incorporated into cultured dairy products to enhance their market value.

Dahi and *lassi* are consumed in different parts of India, regularly as a part of diet from ancient times. The consumption of these products is linked to numerous health benefits. These fermented dairy products can serve as carrier medium through which elephant foot yam can be consumed and its various functional and therapeutic benefits can be made use of. Also, incorporation of elephant foot yam in these foods can enhance its appeal and palatability and thereby, can have a positive impact on the consumption pattern. Since consumption of functional foods containing nutraceuticals is being highly encouraged, *dahi* and *lassi* produced with incorporation elephant foot yam could be of potential interest.

Yam powder obtained from 10 min cooked EFY dried at 60°C in a tray drier was blended into milk for the preparation of *dahi*. Further, psyllium-husk powder was added to the milk-yam blend, because of the former's hydrocolloid nature (fibre content) which was expected to help stabilize the EFY-milk dispersion (Annexure-1). A response surface methodology (RSM) experiment was designed incorporating the elephant foot yam solids (EFYS), psyllium (PSY) and milk fat (MF) in the range of 0.5-2.0%, 0.1-0.3% and 1.5-4.5%, respectively as process variables.

The responses generated in terms of sensory properties and physical attributes (Hunter colour parameters and water holding capacity) and textural attributes are discussed below.

4.2.1 Sensory properties of *dahi* as influenced by process variables

Dahi manufactured by incorporating elephant foot yam solids (EFYS) and psyllium (PSY) was evaluated for its sensory properties viz., appearance, firmness, flavour, consistency and mouth-feel on a 5-point scale. The sensory scores of these parameters as obtained are presented in table RD65. Table RD66 gives various coefficients of the relevant quadratic models for the sensory properties of *dahi* as a function of various process variables viz. EFYS, PSY and MF (milk fat).

Table RD65: Box-Behnken RSM design for three independent process variables at three levels each

Run No.	Standard order	Block	Actual level of variables			Coded level of variables		
			EFYS (%)	PSY (%)	MF (%)	A: EFYS	B: PSY	C: MF
1	17	1	1.25	0.2	3.0	0	0	0
2	1	1	0.50	0.1	3.0	-1	-1	0
3	3	1	0.50	0.3	3.0	-1	+1	0
4	8	1	2.00	0.2	4.5	+1	0	+1
5	13	1	1.25	0.2	3.0	0	0	0
6	15	1	1.25	0.2	3.0	0	0	0
7	4	1	2.00	0.3	3.0	+1	+1	0
8	12	1	1.25	0.3	4.5	0	+1	+1
9	11	1	1.25	0.1	4.5	0	-1	+1
10	2	1	2.00	0.1	3.0	+1	-1	0
11	16	1	1.25	0.2	3.0	0	0	0
12	7	1	0.50	0.2	4.5	-1	0	+1
13	6	1	2.00	0.2	1.5	+1	0	-1
14	14	1	1.25	0.2	3.0	0	0	0
15	5	1	0.50	0.2	1.5	-1	0	-1
16	10	1	1.25	0.3	1.5	0	+1	-1
17	9	1	1.25	0.1	1.5	0	-1	-1

*EFYS-elephant foot yam solids, PSY-psyllium, MF-milk fat

The appearance score varied from 3.8 to 4.2. The minimum appearance score (3.8) was obtained for run 7 (2% EFYS, 0.3% PSY and 3% MF), 12 (0.5% EFYS, 0.2% PSY and 4.5% MF) and 13 (2.0% EFYS, 0.2% PSY and 1.5% MF) while the maximum appearance score (4.2) was obtained for run1 (1.25% EFYS, 0.2% PSY and 3.0% MF) (Table RD66). A non-significant model F value (Table RD67), however, suggested that the process variables studied did not have any definite impact on the appearance of EFY-containing *dahi*.

Table RD66. Sensory attributes of *dahi* manufactured as per the Box-Behnken design of response surface methodology

RUN	EFYS (%)	PSY (%)	MF (%)	AS*	FMS*	FLS*	CS*	MS*
1	1.25	0.2	3.0	4.2	4.2	3.9	3.9	3.6
2	0.50	0.1	3.0	4.1	3.9	3.9	3.6	3.4
3	0.50	0.3	3.0	4.0	3.9	3.7	3.7	3.4
4	2.00	0.2	4.5	4.0	3.7	3.7	3.5	3.0
5	1.25	0.2	3.0	4.0	4.0	3.8	3.7	3.4
6	1.25	0.2	3.0	3.9	4.0	3.8	3.7	3.3
7	2.00	0.3	3.0	3.8	3.7	3.7	3.4	3.0
8	1.25	0.3	4.5	4.0	4.0	3.9	3.7	3.4
9	1.25	0.1	4.5	3.9	4.2	3.9	4.0	3.8
10	2.00	0.1	3.0	4.0	3.9	3.9	3.7	3.4
11	1.25	0.2	3.0	4.0	4.1	3.9	3.8	3.6
12	0.50	0.2	4.5	3.8	3.6	3.8	3.4	3.2
13	2.00	0.2	1.5	3.8	3.7	3.7	3.4	3.2
14	1.25	0.2	3.0	3.9	4.0	3.8	3.8	3.5
15	0.50	0.2	1.5	3.9	3.8	3.7	3.5	3.2
16	1.25	0.3	1.5	4.0	3.8	3.8	3.5	3.1
17	1.25	0.1	1.5	4.1	4.3	4.0	4.0	3.9

*scored on a 5-point scale; AS-appearance score; FMS-firmness score; CS-consistency score; FLS-flavour score; MS - mouth-feel score

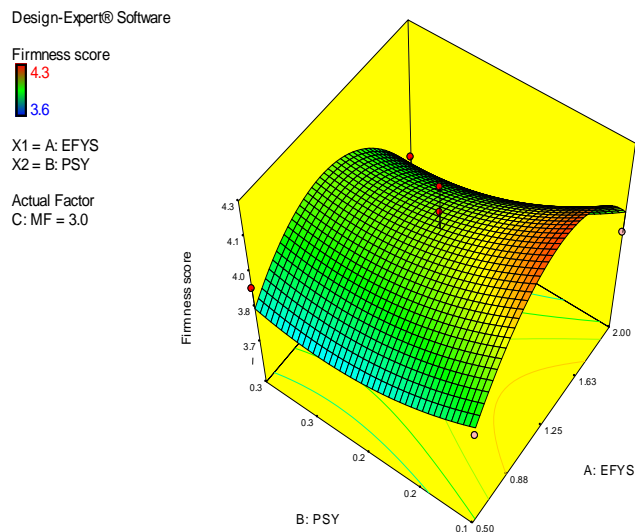
The firmness score of *dahi* as determined sensorially ranged from 3.6 (better than satisfactory) to 4.3 (very good). The lowest sensory firmness score was for *dahi* prepared from combination of 0.5% EFYS, 0.2% PSY and 4.5% MF (run 12), while the highest firmness score was recorded in *dahi* prepared from 1.25% EFYS, 0.1% PSY and 1.5% MF (run 17). The model F-value was found to be significant at 95% confidence level, thus suggesting that model could very well explain the changes in the sensory score due to varying contents of EFYS, PSY and MF. This fact was further corroborated by high coefficient of determination (R^2) value of 0.8749 and a non-significant lack of fit. The adequate precision value was 7.800, appreciably higher than the minimally required value of 4 for high prediction ability. Fig. RD3 depicts the effect of various process variables on

the firmness score of *dahi* as influenced by the process variables. Presumably, psyllium contributed more to the weakening of the casein gel network than to water holding in the product. However, the starch in the yam may be assumed to have led to water holding and strengthening of the casein network at lower levels of EFYS but not at higher levels. Probably, the interaction of the yam starch with the milk-protein network was qualitatively different at lower yam levels from that at higher levels. Further, it was perceived that the higher levels of yam solids imparted an undesirable pastiness to the product i.e. the resulting gel was more plastic or viscous and less elastic.

Excessive use of hydrocolloids has been shown to negatively impact the sensory textural attributes by 'over-stabilization' of texture (Lucey, 2004). Hashim *et al.* (2009) also reported decrease in firmness score at higher levels of date fibre addition in yogurt. The milk-fat level had no effect on the product firmness score (Table RD67). The sensory firmness score of *dahi* could be predicted by the equation given below:

$$\begin{aligned} \text{Firmness score} = & +3.89917 + 1.26667 * \text{EFYS} - 5.09167 * \text{PSY} + 0.016111 * \\ & \text{MF} - 0.66667 * \text{EFYS} * \text{PSY} + 0.044444 * \text{EFYS} * \text{MF} \\ & + 0.5 * \text{PSY} * \text{MF} - 0.52 * \text{EFYS}^2 + 8.25000 * \text{PSY}^2 - 0.03 * \text{MF}^2 \end{aligned}$$

A.



B.

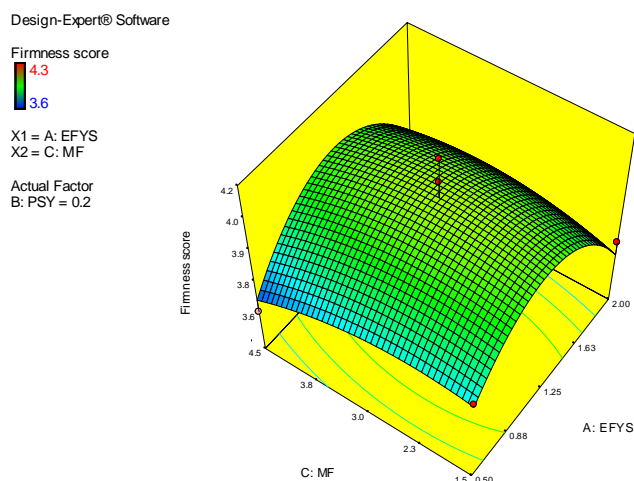


Fig RD3. Response surface plots of firmness score as a function of elephant foot yam solids (EFYS)(%), psyllium (PSY)(%) and milk fat (MF)(%)

Table RD67. Coefficients of quadratic models for the sensory properties of dahi as a function of process variables

Factor	Appearance score	Firmness score	Flavour score	Consistency score	Mouth-feel score
Intercept	4.00	4.06	3.84	3.78	3.48
EFYS (A)	-0.025	-0.025	-0.012	-0.025	-0.075
PSY (B)	-0.038	-0.11*	-0.075**	-0.13**	-0.20**
MF (C)	-0.012	-0.012	0.012	0.025	0.000
AB	-0.025	-0.050	0.000	-0.100	-0.10
AC	0.075	0.050	-0.025	0.050	-0.50
BC	0.050	0.075	0.050	0.050	0.100
A ²	-0.075	-0.29**	-0.11**	-0.26**	-0.29**
B ²	0.050	0.082	0.067*	0.085	0.11
C ²	-0.050	-0.067	-7.5E-003	-0.065	-0.040
Model F-value	0.6766	5.44*	4.99*	5.02*	3.86*
R ²	0.4845	0.8749	0.8652	0.8659	0.8321
Adequate precision	3.367	7.800	7.720	7.184	7.672
Lack of fit	NS	NS	NS	NS	NS

*p<0.05; ** p<0.01; NS-non-significant

The consistency score of dahi ranged from 3.4 to 4.0. The minimum value was recorded for run nos.7 (2.0% EFYS, 0.3% PSY and 3.0% MF), 12 (0.5% EFYS, 0.2% PSY and 4.5 % MF) and 13 (2.0% EFYS, 0.2% PSY and 1.5% MF) whilst the maximum value for run nos. 9 (1.25% EFYS, 0.1% PSY and 4.5% MF) and 17 (1.25% EFYS, 0.1% PSY and 1.5% MF). It showed essentially a similar pattern with regards to the effects of EFYS and psyllium levels in *dahi*. The product's consistency score showed an inverse relationship with the psyllium level ($p \leq 0.01$) particularly at the higher levels of yam solids (Fig.RD4) although the interaction between EFYS and PSY was non-significant. Also, the score peaked near the mid-values in the range of the EFYS level for all values of psyllium, the response surface being convex upward ($p \leq 0.01$).

The fitted quadratic model for the consistency score showed a significant ($p \leq 0.05$) model F value. The adequate precision of the model (viz. 7.184) was desirably high (higher than 4). The non-significant lack of fit implied that model is sufficiently accurate for predicting the consistency score of *dahi*. Response surface curves showing the effect of process variables on the consistency score are presented in Fig RD4. The pastiness contributed by addition of psyllium together with yam powder at higher concentrations might have caused the reduction in the consistency score as noted above. Arora (2006) reported a decrease in body and texture score of yoghurt upon addition of fibre blend comprising psyllium as one of its ingredients. The consistency score of the *dahi* prepared from blend of EFYS and PSY for actual factors could be predicted by the following quadratic model ($p \leq 0.05$)-

$$\text{Consistency score} = +3.39889 + 1.27778 * \text{EFYS} - 3.98333 * \text{PSY} + 0.067778 * \text{MF} - 1.33333 * \text{EFYS} * \text{PSY} + 0.044444 * \text{EFYS} * \text{MF} + 0.33333 * \text{PSY} * \text{MF} - 0.47111 * \text{EFYS}^2 + 8.50000 * \text{PSY}^2 - 0.028889 * \text{MF}^2$$

The mouth-feel score of *dahi*, prepared using different levels of yam solids and psyllium husk ranged from 3.0 (satisfactory, a few criticisms) to 3.9 (good) on a 5-point scale. It was highest for run no. 17 and lowest for run nos. 4 and 7. In a manner similar to consistency score, the mouth-feel score declined linearly with a linear increase in the PSY level ($p \leq 0.01$). Psyllium particles imparting graininess to the product and causing an uneven surface were believed to have led to the decreased mouth-feel score.

The fibre addition was reported to be adversely affecting the mouth-feel score of yoghurt (Hashim *et al.* 2009). The significant quadratic term ($p \leq 0.01$) in the regression equation for mouth-feel score implied that a maximum mouth-feel score was obtained at mid values of EFYS (Fig. RD5). As observed in the case of firmness score and consistency score of *dahi*, the increase in EFYS led to an increased mouth-feel score till a peak was reached; higher levels of EFYS caused a decline in the mouth-feel score. Whilst psyllium had negative impact on the mouth-feel score, the fat level was not perceived to have any effect. Starch added to yoghurt was observed to increase the creamy sensation particularly at lower fat levels (Bruzzone *et al.* 2013). Similar observations have also been reported by Alting *et al.* (2009) and Kanning *et al.* (2012). Fat which is known to provide smooth sensation was unable to affect the mouth-feel score, presumably on account of the predominating role of the other two ingredients in the texture of EFY and psyllium added *dahi*. The equation for predicting the mouth-feel rating of *dahi* prepared using EFY powder and psyllium could be given as-

$$\begin{aligned} \text{Mouthfeel score} = & +3.37944 + 1.58889 * \text{EFYS} - 6.73333 * \text{PSY} + 0.028889 * \\ & \text{MF} - .33333 * \text{EFYS} * \text{PSY} - 0.044444 * \text{EFYS} * \text{MF} + 0.66667 \\ & * \text{PSY} * \text{MF} - 0.51556 * \text{EFYS}^2 + 11.00000 * \text{PSY}^2 - 0.017778 * \text{MF}^2 \end{aligned}$$

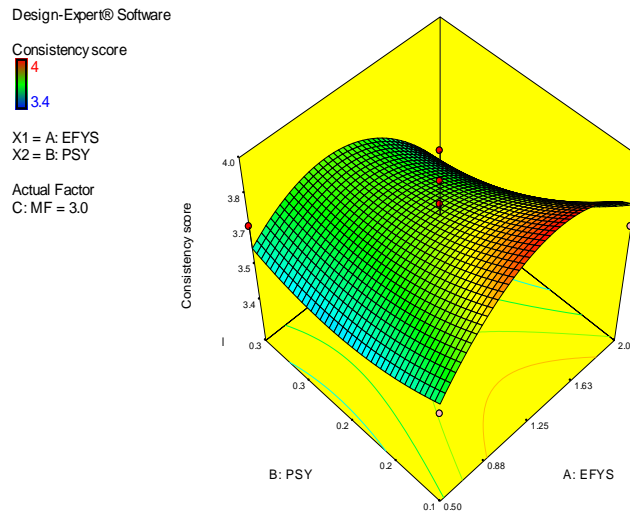
The flavour score as affected by yam solids and milk-fat levels in *dahi* (Fig. RD6 and Table RD67) followed a pattern somewhat similar to that observed in the other sensory attributes discussed above.

Thus, increasing EFYS first caused an increase in the flavour score followed by a reversed impact at higher levels, mid-values showing the highest scores ($p \leq 0.01$) (Fig. RD6). The fat level had no perceivable effect on the flavour score presumably due to the over-riding effect of the other two factors. Incorporation of psyllium overall tended to decrease the flavour score ($p \leq 0.01$) but at lower levels increasing psyllium level resulted in a decreasing score but at higher levels it showed an opposite trend.

The maximum value of flavour score was noted for the run no. 17 (1.25% EFYS, 0.1% PSY and 1.5% MF) and the minimum value was noted for run nos. 3, 4, 7, 13 and 15. The relevant quadratic model for predicting the flavour score of the EFYS and PSY-added *dahi* ($R^2 = 0.86$) is given below:

$$\begin{aligned} \text{Flavor score} = & +4.04389 + 0.52778 * \text{EFYS} - 4.45000 * \text{PSY} - 0.010556 * \text{MF} \\ & + 0.000000 * \text{EFYS} * \text{PSY} - 0.022222 * \text{EFYS} * \text{MF} + 0.333333 * \\ & \text{PSY} * \text{MF} - 0.19111 * \text{EFYS}^2 + 6.75000 * \text{PSY}^2 - 3.33333\text{E-}003 * \text{MF}^2 \end{aligned}$$

A.



B.

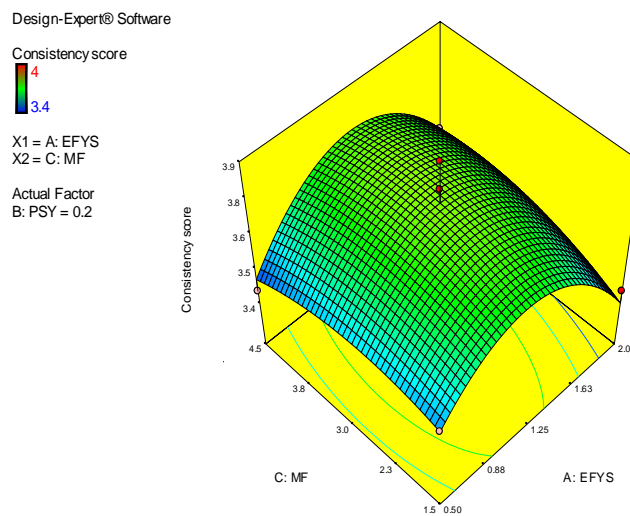
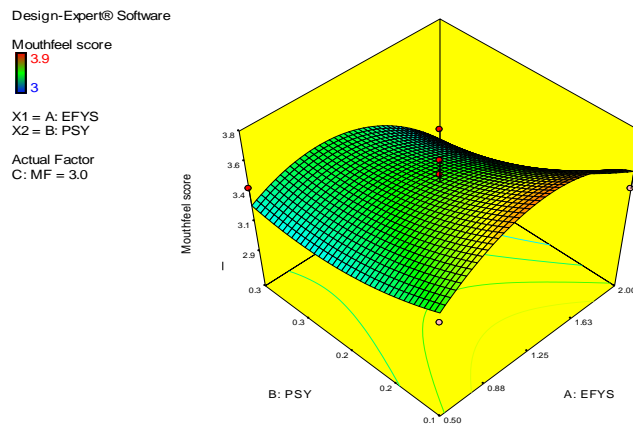
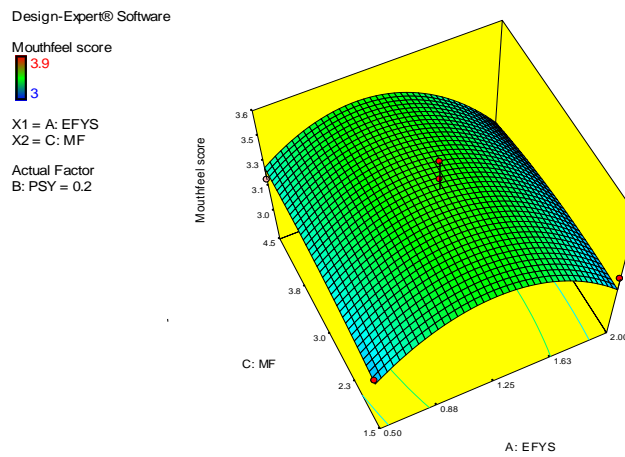


Fig RD4. Response surface plots of consistency score as a function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF) (%)

A.



B.



C.

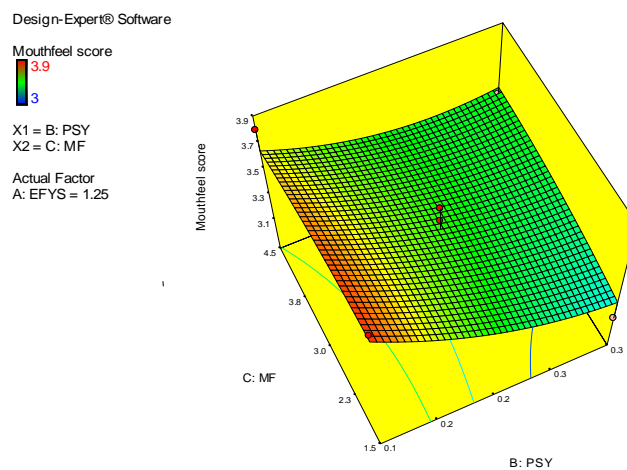


Fig RD5. Response surface plots of mouthfeel score as a function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF) (%)

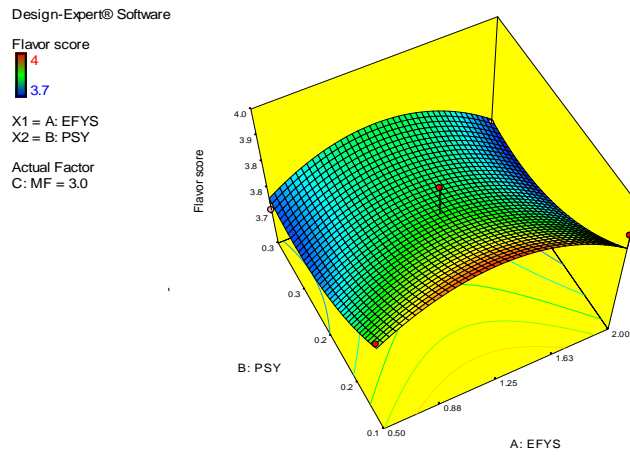
4.2.2 Whiteness Index and water holding capacity of *dahi* as influenced by the process variables

Whiteness index represents the overall whiteness of the product and cumulatively shows the appearance effect of all three Hunter colour parameters (L^* , a^* and b^*). The degree of whiteness is usually linked to consumer's acceptance of the product. The whiteness value varying with process factors are displayed in Table RD 67. The whiteness index of *dahi* varied from 76.51 to 85.70. The most white *dahi* was prepared from milk dispersion containing 2.0% EFYS, 0.2% PSY and 1.5% MF while *dahi* displaying least whiteness value was prepared from milk containing 0.5% EFYS, 0.3% PSY and 3% MF.

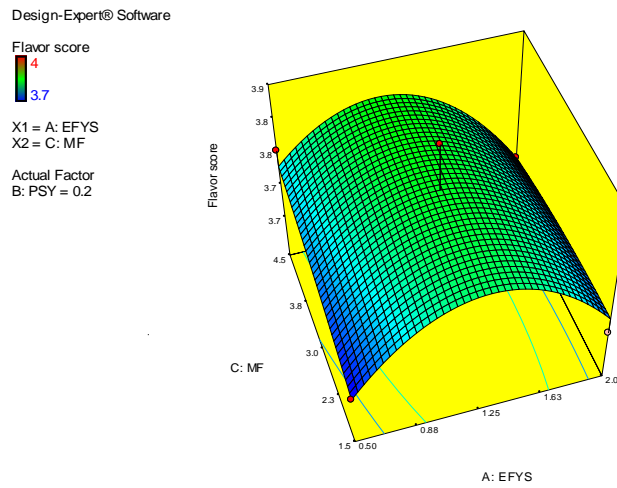
The regression analysis presented in Table RD69 further reveals that coefficient of determination (R^2) was 0.9029 and the lack of fit test of the model was not significant indicating that the model is sufficiently accurate for predicting the whiteness value of *dahi*. The model fitted the data well, the model F value being 17.54 ($p \leq 0.01$). The adequate precision was much higher at 14.958 than what is required for good prediction.

As evident from Fig. RD7, the whiteness index of *dahi* showed a linear decrease with increasing EFYS. Increasing yam solids imparted increasing browning to the *dahi*, brown colour being associated with the yam powder. Milk fat, on the other hand, significantly enhanced the whiteness value of *dahi* ($p \leq 0.01$), as depicted in Fig RD7. Milk fat globules being able to scatter light in the visible spectrum (Fox and McSweeney, 1998), a higher fat level can be considered to have made the product whiter. Raju and Pal (2009) and Sharique (2013) also observed an increased in whiteness with increased milk fat content. Although the psyllium level had no direct impact on the whiteness (Table RD69), it tended to hinder the whitening effect of milk-fat in the yam-containing *dahi*, the interaction between the two being significant ($p \leq 0.05$). Thus at lower levels of PSY, the WI increase effected by milk fat in the range studied was appreciably greater than the WI increase at higher levels of the fiber (Fig. RD7(c)).

A.



B.



C.

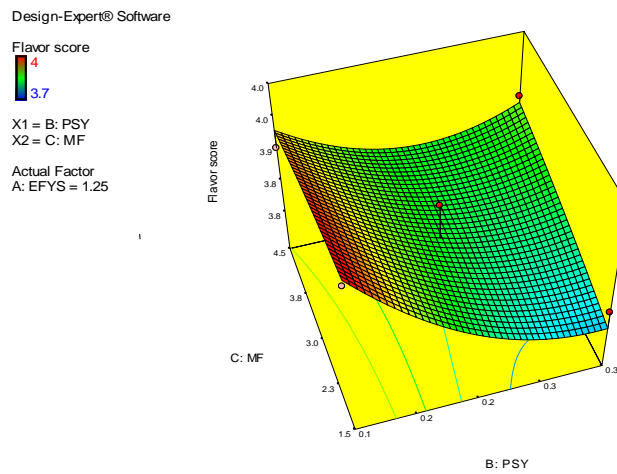


Fig RD6. Response surface plots of flavor score as a function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF) (%)

The whiteness index of *dahi* prepared by varying process variables could be estimated by following quadratic model ($R^2 = 0.90$):

$$WI = +77.68887 - 6.63321 * EFYS + 48.03492 * PSY + 2.75514 * MF - 9.15583 * EFYS * PSY + 1.17956 * EFYS * MF - 6.48735 * PSY * MF + 0.70846 * EFYS^2 - 45.91095 * PSY^2 - 0.25403 * MF^2$$

Table RD68. Whiteness index and water holding capacity of *dahi* manufactured as per the Box-Behnken design of response surface methodology

RUN	EFYS (%)	PSY (%)	MF (%)	Whiteness index	Water holding capacity (%)
1	1.25	0.2	3	81.22	94.12
2	0.50	0.1	3	83.74	85.41
3	0.50	0.3	3	85.70	91.40
4	2.00	0.2	4.5	83.24	91.82
5	1.25	0.2	3	82.86	93.83
6	1.25	0.2	3	82.84	94.83
7	2.00	0.3	3	79.76	91.39
8	1.25	0.3	4.5	82.14	93.94
9	1.25	0.1	4.5	85.17	95.84
10	2.00	0.1	3	80.54	95.19
11	1.25	0.2	3	83.39	93.04
12	0.50	0.2	4.5	85.48	93.10
13	2.00	0.2	1.5	76.51	91.28
14	1.25	0.2	3	82.18	90.09
15	0.50	0.2	1.5	84.06	81.86
16	1.25	0.3	1.5	79.71	79.76
17	1.25	0.1	1.5	78.84	78.22

The percentage of concentrated yoghurt obtained after static or dynamic drainage is commonly used to define water holding capacity (WHC) (Sodini *et al.* 2004) and is an important property for gel systems. The water holding capacity of *dahi* prepared in the RSM experiment using different process variables is presented in Table RD68. The relevant regression coefficients are given in Table RD69. The WHC of *dahi* ranged from 78.22 to 95.84. The *dahi* prepared from

milk blend of 1.25% EFYS, 0.1% PSY and 1.5% MF possessed the least WHC, while that from milk blend containing 1.25% EFYS, 0.1% PSY and 1.5% MF had maximum WHC.

Table RD69. Coefficients of quadratic models for the whiteness index and water holding capacity of *dahi* as a function of process variables

Factor	Whiteness Index	Water holding capacity
Intercept	82.50	93.18
EFYS (A)	-2.37**	2.24
PSY (B)	-0.12	0.23
MF (C)	2.11**	5.45**
AB	-0.69	-2.45
AC	1.33	-2.68
BC	-0.97*	-0.86
A ²	0.40	0.12
B ²	-0.46	-2.45
C ²	-0.57	-3.79*
Model F value	17.54**	5.08*
R ²	0.9029	0.8673
Adequate precision	14.958	6.959
Lack of fit	NS	NS

*p<0.05; ** p<0.01; NS-non-significant

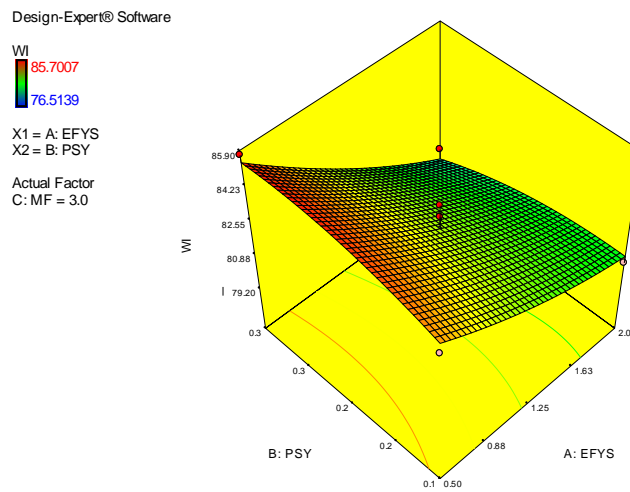
Perusal of Fig RD8 indicates that water holding capacity of *dahi* was affected in a significant ($p \leq 0.01$) manner by the milk fat content. As the fat content increased, the water holding capacity also showed increasing behaviour, the increase being larger at lower levels of EFYS and psyllium, although the interactions were non-significant. Further, the increase in WHC was rapid in the lower range of the fat content than in the higher range. On similar lines, Becker and Puhan (1981), Keogh and O’Kennedy (1998) and Hussain (2013) observed increasing WHC with increasing fat levels (yoghurt, stirred yoghurt and *dahi* respectively). The EFYS and PSY both having potential hydrocolloid action

individually affected the WHC in a positive but non-significant manner. Lobato-Calleros *et al.* (2014) noticed a decrease in syneresis of yoghurts incorporated with starch. Starches are known to retain substantial quantity of water into weak gel structures (Luo and Gao, 2011).

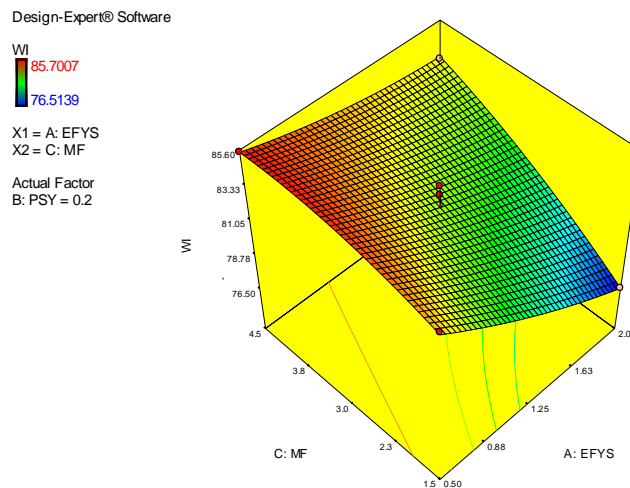
The WHC of the composite dahi can be predicted by following quadratic model:

$$WHC = +32.94928 + 16.11056 * EFYS + 158.46917 * PSY + 17.84989 * MF - 32.63333 * EFYS * PSY - 2.37778 * EFYS * MF - 5.73333 * PSY * MF + 0.21378 * EFYS^2 - 245.47500 * PSY^2 - 1.68322 * MF^2$$

A.



B.



C.

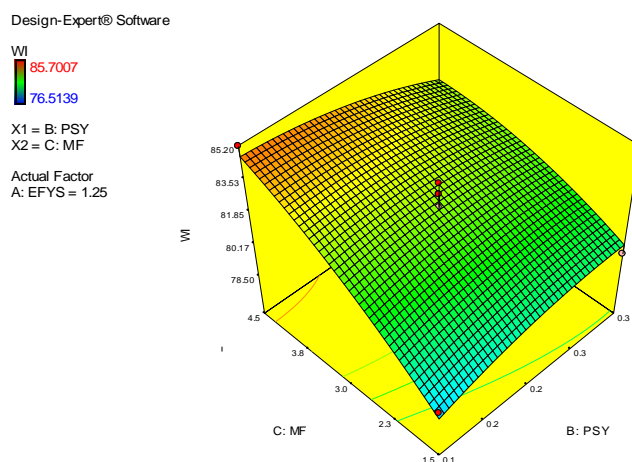


Fig RD7. Response surface plots of whiteness index of *dahi* as function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)

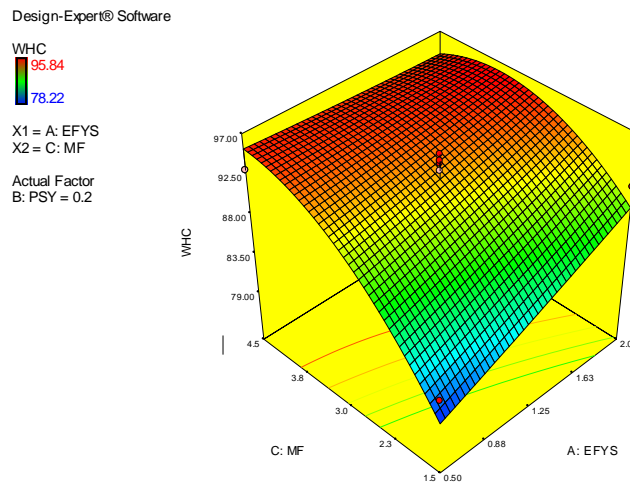
4.2.3 Instrumental texture parameters of yam-added *dahi* as influenced by the process variables

Yam- and psyllium-containing *dahi* obtained from various experimental runs was subjected to the textural analysis and data were generated on various textural attributes namely, firmness (N), work of adhesion (Ns), work of shear (Ns) and stickiness (N) employing Texture Analyzer in a single-cycle compression mode (Table RD70). Table RD71 shows the coefficients of the linear regression model fitted to the data on textural attributes.

Firmness value is the peak force obtained during compression by the probe. The instrumental firmness of *dahi* varied from 2.39 N to 4.71 N. The *dahi* obtained from milk-yam blend containing 0.5% EFYS, 0.1% PSY and 3% MF (run 2) was most firm while that from that containing 1.25% EFYS, 0.3% PSY and 1.5% MF was least firm (run16). It was observed that with increasing yam solids level the product's firmness decreased linearly, the decrease being highly significant ($p \leq 0.01$) (Table RD70 and Fig. RD9). The linear regression model fitted the firmness data best. The loss in strength of gel network, contributing to the decreased firmness, might have been possibly due to high association of polysaccharide chains among themselves, which did not integrate into the protein network and inhibited casein micelles aggregation (Sandoval-Castilla *et al.* 2004).

Ledward (1993) reported that at a certain total polysaccharide-protein polymer concentration (usually above 4%) phase separation occurs decreasing the protein gel strength. While psyllium decreased the firmness of *dahi*, the milk-fat level increased it; however, these effects were non-significant.

A.



B.

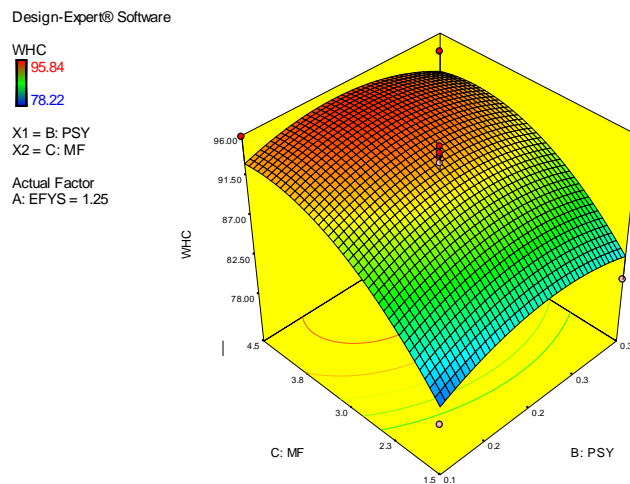


Fig. RD8. Response surface plots of water holding capacity of *dahi* as function of elephant foot yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF) (%)

Conflicting reports regarding the effect of fibre on firmness of food gels are found in literature. Adverse effect of fibre on firmness of yoghurt was observed by Staffolo *et al.* (2004) and Sendra *et al.* (2010) which was considered to be due to

probable formation of fiber aggregates within themselves which interfered with yoghurt structure. The firmness of *dahi* as related to the ingredient levels could be expressed by the following linear model:

$$\text{Firmness (N)} = +4.58762 - 0.98833 * \text{EFYS} - 3.15000 * \text{PSY} + 0.27083 * \text{MF}$$

The work of shear (WOS), i.e., the area under the compression curve (down stroke), represents the amount of energy required to perform the shearing process. WOS ranged from 24.72 Ns to 59.77 Ns.

Table RD70. Texture attributes of *dahi* prepared as per the 3-factor RSM experiment (Box-Behnken design)

RUN	EFYS (%)	PSY (%)	MF (%)	Firmness (N)	WA* (Ns)	WS* (Ns)	Stickiness (N)
1	1.25	0.2	3	3.88	-15.18	43.37	-1.19
2	0.50	0.1	3	4.71	-15.25	59.77	-1.27
3	0.50	0.3	3	3.95	-12.95	48.86	-1.08
4	2.00	0.2	4.5	2.53	-14.30	38.81	-0.86
5	1.25	0.2	3	4.17	-15.02	41.54	-1.31
6	1.25	0.2	3	3.05	-17.65	50.00	-1.12
7	2.00	0.3	3	2.83	-11.46	40.27	-0.88
8	1.25	0.3	4.5	3.86	-14.12	53.08	-0.93
9	1.25	0.1	4.5	4.25	-20.56	56.56	-1.59
10	2.00	0.1	3	3.89	-17.67	47.72	-1.39
11	1.25	0.2	3	3.49	-14.51	40.38	-1.12
12	0.50	0.2	4.5	4.73	-16.67	48.92	-1.53
13	2.00	0.2	1.5	2.62	-10.05	30.54	-0.77
14	1.25	0.2	3	2.63	-9.42	31.65	-0.73
15	0.50	0.2	1.5	4.41	-9.43	36.93	-0.95
16	1.25	0.3	1.5	2.39	-10.8	40.18	-0.69
17	1.25	0.1	1.5	2.70	-5.68	24.72	-0.54

*WA- work of adhesion; WS- work of shear

The energy required for shearing the *dahi* gel was recorded to be maximum for the product prepared using milk blend consisting of 0.5% EFYS, 0.1% PSY and 3% MF, and minimum for that from the mix containing 1.25% EFYs, 0.1% PSY and 1.5% MF. Although WOS was decreased by increasing

EFYS or PSY levels, the decline was non-significant. Increasing milk-fat level significantly increased ($p \leq 0.01$) the WOS. The energy required for breaking the *dahi* structure increased in a linear manner with increasing milk fat concentration. The increase in shearing energy indicated the strengthening effect of milk fat on the gel network. Partial solidification of milk fat in the fat globules may be one of the causes of the increased WOS.

Table RD71. Coefficients of linear multiple regression equations for the instrumental texture properties of *dahi* at 5°C as a function of process variables

Factor	Firmness	Work of shear	Work of adhesion	Stickiness
Intercept	3.53	43.14	-13.57	-1.06
EFYS (A)	-0.74**	-4.64	0.10	0.12
PSY (B)	-0.32	-0.80	1.23	0.15
MF (C)	0.41	8.13**	-3.71**	-0.25**
Model F value	7.21**	4.38*	5.28**	4.97*
R ²	0.6247	0.5025	0.5495	0.5345
Adequate precision	8.626	7.181	7.332	7.186
Lack of fit	NS	NS	NS	NS

* $p < 0.05$; ** $p < 0.01$; NS-non-significant

A.

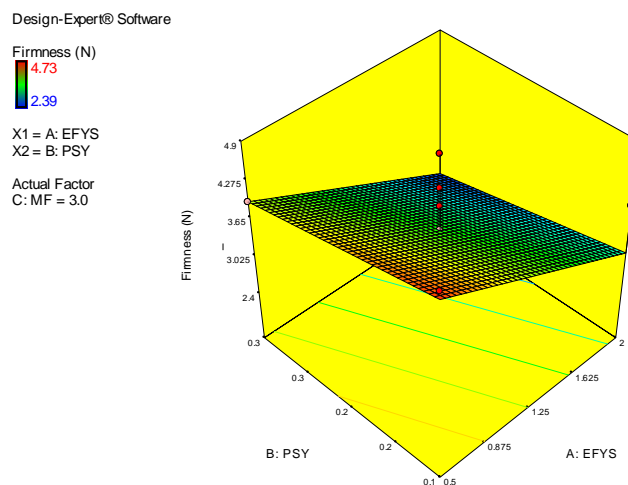
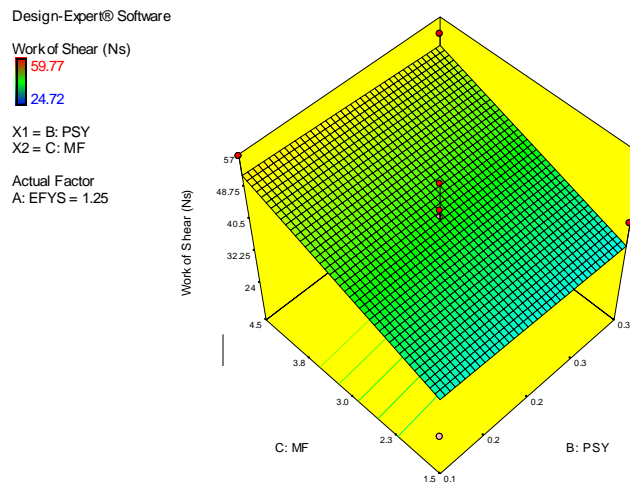


Fig RD9. Response surface plots showing firmness (N) as a function of elephant yam solids (EFYS) (%) and psyllium (PSY)(%)

Further, in homogenized systems, the interaction between fat globule membrane and protein acts as structural promoters and enhances the gel strength (Cho *et al.* 1991; Cobos *et al.* 1995). Aguilera and Kessler (1989) reported increased curd strength due to interaction between fat globule membrane and protein matrix. The work done during shearing of *dahi* can be predicted by the following linear regression model:

$$WOS (Ns) = +36.21779 - 6.19000 * EFYS - 7.97500 * PSY + 5.41667 * MF$$

A.



B.

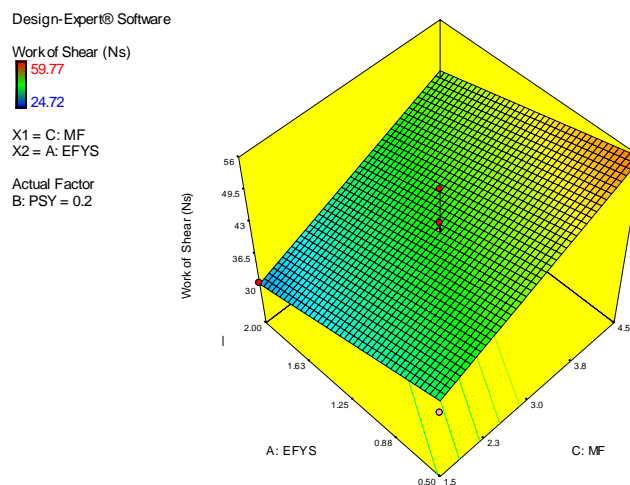


Fig RD10. Response surface plots showing work of shear (Ns) as a function of elephant yam solids (EFYS) (%), psyllium (PSY)(%) and milk fat (MF)(%)

Work of adhesion (WOA) is the work necessary to overcome the attractive force between the surface of the product and surface of the probe. The area lying under the negative curve during the decompression cycle was reported as WOA. The effect of various process factors on the energy consumed during the lifting of probe from the surface of *dahi* is visualized in Fig RD11. The peak value for work of adhesion was recorded in *dahi* made from milk dispersion containing 1.25% EFYS, 0.1% PSY and 4.5% MF while the lowest value was recorded in the product prepared from milk-yam mix containing 1.25% EFYS, 0.1% PSY and 1.5% MF. As observed from the linear regression coefficients (Table RD70), WOA increased slightly with increasing yam solids or psyllium in the blend, the effects however being non-significant. These observations were in line with those reported in case of Misti *dahi* where Raju and Pal (2014) found no significant change in the stickiness and work of adhesion values upon fiber fortification in misti *dahi*. On the other hand, increasing MF level significantly decreased WOA ($p \leq 0.01$) (Fig. RD11). The decrease in work of adhesion was apparently due to lesser energy required to overcome the attractive forces between the surface of the product and surface of the probe (Giri *et al.* 2014), which may in turn be attributed to the increasing concentration of fat at the interface.

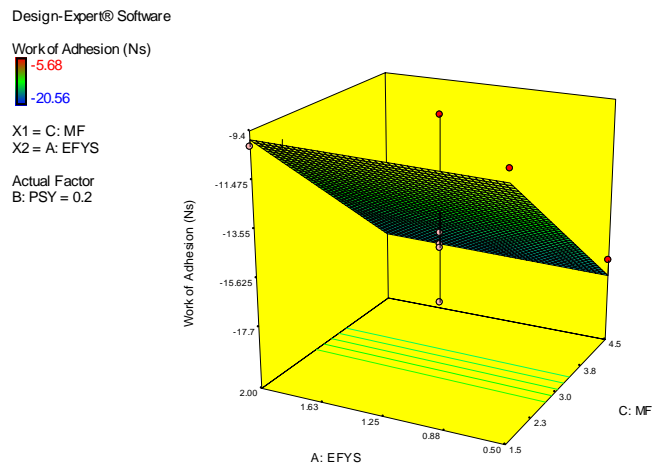
The work of adhesion in actual factors could be predicted by following linear equation-

$$WOA (Ns) = - 8.77760 + 0.13667 * EFYS + 12.28750 * PSY - 2.47417 * MF$$

Stickiness, measured as the height of the negative (up-stroke) peak, showed a pattern very similar to the work of adhesion as influenced by the levels of EYS, psyllium and milk-fat i.e. it decreased significantly ($p \leq 0.01$) with increasing yam solids, but declined non-significantly with psyllium and milk-fat (Table RD 71; Fig RD12). The maximum value of stickiness was obtained from *dahi* containing 1.25% EFYS, 0.1% PSY and 4.5% MF, while the minimum value was recorded for *dahi* containing 1.25% EFYS, 0.1% PSY and 1.5% MF. Reduction in adhesiveness with increasing fat content was also observed by Brighenti *et al.* (2008) in cream cheese and by Wasnik *et al.* (2013, in press) in *Santra burfi*. The stickiness could be estimated by the following linear regression equation:

$$Stickiness (Ns) = - 1.06213 + 0.15500 * EFYS + 1.51250 * PSY - 0.16333 * MF$$

A.



B.

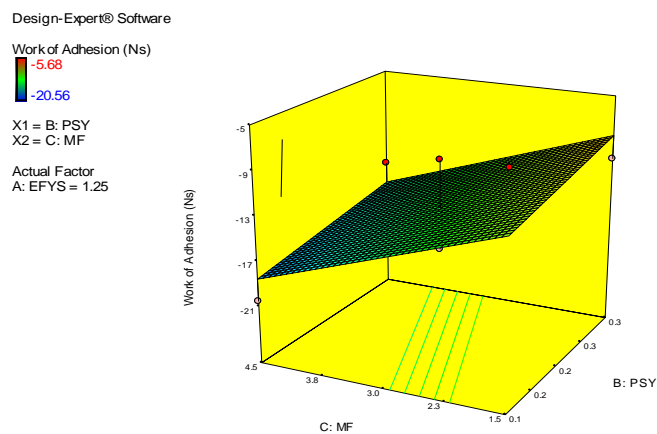
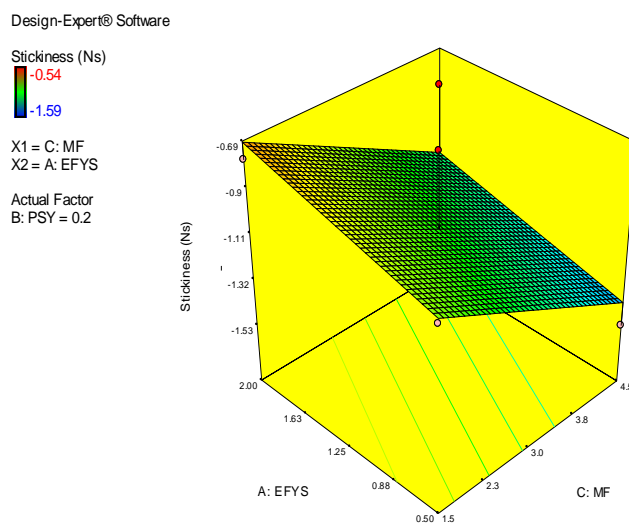


Fig RD11. Response surface plots showing work of adhesion (Ns) as function of elephant yam solids (EFYS) (%), psyllium (PSY)(%) and milk fat (MF)(%)

4.2.4 Selection of the optimized process variables for the preparation of *dahi*

Based on the effects of the three process variables (RSM factors) on various properties (responses) of yam-containing *dahi* as discussed above, an attempt was made to work out the optimum combination of the former using the RSM optimization technique (Design Expert 7.0.0).

A.



B.

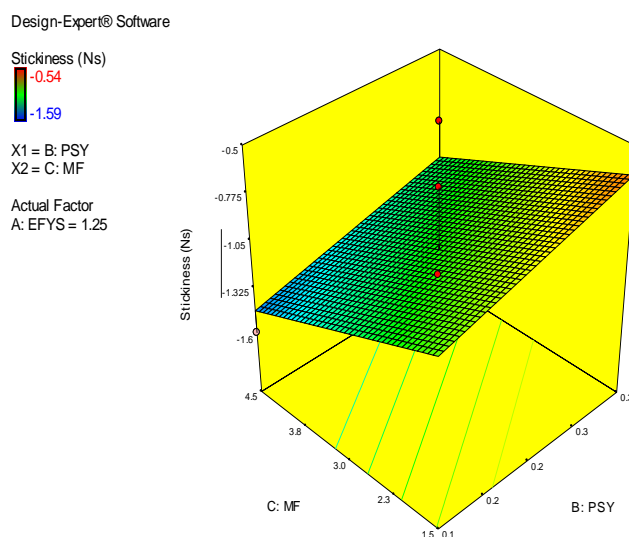


Fig. RD12. Response surface plots showing stickiness (N) as function of elephant yam solids (EFYS) (%), psyllium (PSY) (%) and milk fat (MF)(%)

The combination of factors thus obtained was expected to yield the most acceptable product. The criteria that were selected to obtain the optimized solution are delineated in Table RD72. The optimized combination having highest desirability, given by the software was chosen (Table RD72; Desirability- 92.4%). Verification of the optimized formulation was carried out by comparing the actual

experimental data with the predicted values of the product parameters in terms of sensory attribute scores.

Table RD72. Goals set for constraints to get an optimum combination of the *dahi*-making variables

Factor	Goal	Lower limit	Upper limit
A: EFYS (%)	In range	0.5	2.0
B: PSY (%)	In range	0.1	0.3
C: MF (%)	In range	1.5	4.5
Appearance score	maximize	3.8	4.2
Firmness score	maximize	3.6	4.3
Flavour score	maximize	3.7	4.0
Consistency score	maximize	3.4	4.0
Mouth-feel score	maximize	3.0	3.9

Table RD73. Optimized solution for *dahi*-making variables

A: EFYS (%)	1.25
B: PSY (%)	0.1
C: MF (%)	2.1

Table RD74 depicts comparison of the predicted values with the actual values. The observed values (experimental) and predicted values were subjected to students t-test analysis. The t-test indicated that there was no significant difference between predicted and observed values. It was thus possible to successfully validate the optimized product formulation.

Table RD74 Predicted and observed response values for optimized *dahi*

Parameter	Predicted Value	Actual Value	t_{0.05}
Colour and appearance score	4.1	4.2±0.2	0.88 ^{ns}
Firmness score	4.3	4.1±0.1	2.07 ^{ns}
Flavour score	4.0	4.1±0.1	1.43 ^{ns}
Consistency score	4.0	4.1±0.3	0.51 ^{ns}
Mouth-feel score	3.8	3.8±0.3	0.36 ^{ns}

*Sensory score on 5 point scale

4.2.5 Compositional analysis of *Dahi* from the optimized formulation

The *dahi* prepared from the optimized formulation of milk-yam blend variables was subjected to compositional analysis using standard analytical methods. The results are presented in Table RD75.

4.2.6 *Lassi* obtained from optimized *dahi*

Dahi obtained from milk blended with elephant foot yam solids and psyllium husk at optimum levels was converted into *lassi*. *Lassi* offers a unique and easy way for further value addition to *dahi*. It can easily be prepared by blending with water and sugar or salt with spices until frothy. Both sweet and salty variants of *lassi* were prepared from the yam-psyllium *dahi*.

4.2.6.1 Sweet *lassi*

For preparation of sweet *lassi*, the sugar level was fixed at 15% as per the standard procedure, and the level of dilution with water was varied. Sensory evaluation was conducted to arrive at an optimum level of dilution. Table RD76 presents the sensory scores of *dahi* as influenced by the degree of dilution.

Table RD75. Composition of yam-added *dahi*

Constituent		Amount
Total solids (%)		13.30±0.06
Fat (%)		3.10±0.01
Protein (%)		3.80±0.03
Ash (%)		0.86±0.01
Dietary fibre (%)		0.13±0.01
Carbohydrates* (%)		5.54
Total phenol (mg GAE/ g <i>dahi</i> powder)	Water extract	1.09 ± 0.08
	Methanolic extract	2.18 ± 0.03
DPPH activity (µmole TE / g <i>dahi</i> powder)	Water extract	0.13 ± 0.01
	Methanolic extract	0.31 ± 0.00
ABTS activity (µmole TE/ g <i>dahi</i> powder)	Water extract	2.08 ± 0.03
	Methanolic extract	2.28 ± 0.03

*by difference; mean ± se, n=3; freeze dried *dahi* powder

The colour and appearance score of *lassi* varied significantly with the degree of dilution ($p \leq 0.05$). A slight increase in the appearance score was observed in the product with 44.4% dilution as against the one with 50.0% dilution. A dilution level of 37.5% showed significantly higher score than any other dilution. Further decrease in the dilution to 33.5%, caused a decrease in the colour score. The effect of dilution level on the product appearance score could be related to the thinning effect of added water.

As shown by the data presented in Table RD76, the level of dilution of *dahi* with water had no significant effect on the flavour score of *lassi*. The sensory scores for consistency of the product as influenced by the dilution level followed a similar pattern as in the case of appearance score (Table RD75). With decreasing dilution (from 50.0%), the consistency score increased, the increase being significant at 37.5% dilution.

Table RD76. Sensory scores of sweet *lassi*

Sensory Attribute [#]	Dilution level (water: <i>dahi</i>)				F ratio
	1.0:1.0 (50.0%)	0.8:1.0 (44.4%)	0.6:1.0 (37.5%)	0.5:1.0 (33.3%)	
Colour and appearance score	7.28±0.03 ^a	7.45±0.05 ^{ab}	7.70±0.17 ^b	7.38±0.08 ^a	9.667*
Flavour score	7.40±0.05	7.40±0.00	7.50±0.00	7.43±0.12	1.684
Consistency score	7.42±0.14 ^a	7.67±0.29 ^{ab}	7.93±0.12 ^b	7.50±0.00 ^{ab}	5.303*
Mouthfeel score	7.33±0.14	7.67±0.29	7.77±0.25	7.50±0.00	2.600
Overall acceptability	7.40±0.10 ^a	7.43±0.12 ^a	7.93±0.12 ^b	7.43±0.06 ^a	19.667**

*p<0.05; **p<0.01; means with different superscripts in a row differ significantly as determined by Tukey's test; # Rated on a 9-point hedonic scale; @ Figures in parentheses indicate percent dilution

Simultaneously, there was a slight but non-significant increase in the mouth-feel score when the dilution was reduced to 37.5%, beyond which it showed a marginal decline. Thus, whilst a certain level of dilution imparted the desired consistency to *lassi*, increasing dilution with water (from 50 to 33%) had no significant effect on the mouth-feel perception. Further perusal of Table RD76 shows that the overall acceptability score, in consonance with the appearance and consistency scores, improved with decreasing dilution, the score for 37.5% dilution being significantly higher than that for 50% dilution ($p \leq 0.01$). However, reduction in dilution to 33.5% resulted in a decreased palatability of the *lassi* as indicated by the significantly decreased overall acceptability score. The maximum score 7.9 (very close to 'like very much', 8.0) registered in the case of *lassi* from 37.5% diluted yam-containing *dahi* represented a high sensory acceptability of the product. The conventional sweetened *lassi* is generally flavoured for enhanced consumer acceptance. Therefore, the product in the present study was flavoured with various flavourings namely mango, pineapple, rose and vanilla, using synthetic essences blended @ 0.1% and the resulting *lassi* evaluated for its

appearance, flavour and overall acceptability on 9 point hedonic scale. The scores are presented in Table RD77.

Table RD77. Sensory scores of sweet *lassi* as affected by different flavourings

Flavouring	Appearance	Flavour score	Overall acceptability
Mango	7.33±0.16	7.17±0.17 ^a	7.00±0.00 ^b
Pineapple	7.25±0.14	6.67±0.17 ^a	7.00±0.00 ^b
Rose	7.33±0.16	8.17±0.17 ^b	7.83±0.17 ^c
Vanilla	7.25±0.14	6.50±0.29 ^a	6.50±0.29 ^a
F ratio	0.095	44.000 ^{**}	13.500 ^{**}

^{**}p<0.01; means with different superscripts in a column differ significantly as determined by Tukey's test

As is evident from the sensory scores of flavoured *lassi*, different flavour essences added in *lassi* were unable to influence the sensory appearance score in a significant manner. Rose flavoured *lassi* was rated significantly higher for flavour (8.2: better than 'like very much' score of 8) than *lassi* with other flavourings ($p \leq 0.01$). There was no significant difference among other flavourings although mango flavoured *lassi* was scored slightly higher (7.2) than the rest. The preference for vanilla *lassi* was the lowest (6.5). The overall acceptability score of flavoured *lassi* followed a trend similar to that for flavour score, rose-flavoured *lassi* being rated the highest (7.8) and significantly higher ($p \leq 0.01$) than *lassi* with other flavourings (Table RD77).

4.2.6.2 Salted *lassi*

The salted variant of *lassi* was prepared in accordance with Hussain (2008) and varying dilution level was studied to achieve an acceptable consistency. The salted *lassi* was flavoured using cumin and black pepper and subjected to sensory analysis by a panel of judges. The sensory scores recorded on 9 point hedonic scale are presented in Table RD78. The appearance was non-significantly affected by the dilution level, as the appearance score for *lassi* ranged from 7.38 to 7.47, on 9 point Hedonic scale. The flavour score of the salted *lassi* ranged from 7.50 to 7.87.

Table RD78. Sensory scores of salted *lassi*

Attribute	Dilution level (water: <i>dahi</i>)			F ratio
	0.9:1.0 (47.4%)	0.8:1.0 (44.4%)	0.7:1.0 (41.2%)	
Appearance	7.38±0.24	7.43±0.06	7.47±0.06	1.267
Flavour	7.53±0.24	7.87±0.12	7.50±0.00	5.349*
Consistency	7.55±0.09 ^a	7.93±0.12 ^b	7.42±0.14 ^a	15.540**
Mouth-feel	7.33±0.14	7.50±0.00	7.30±0.05	4.429
Overall acceptability	7.33±0.29	7.83±0.29	7.40±0.10	3.755

*p<0.05; **p<0.01; means with different superscripts in column differ significantly as determined by Tukey's test

A significant increase was noticed in flavour score when dilution level was increased from 41.2% to 44.4% (7.50 to 7.87). Further dilution caused a sharp decline in the flavour score. As the salt and spice level were kept constant, dilution with water, conceivably caused reduction in flavour intensity produced by salt-spice mix. The consistency score of salted *lassi* varied significantly with the water addition. The sensory score for consistency changed from 7.42 to 7.93 as dilution percentage increased from 41.2% to 44.4%. Further hiking the water level in *lassi* led to reduction in the consistency score. Similar kind of variation was noticed in the sensory mouthfeel score of salted *lassi*.

The overall acceptability score which can be associated with perceptible likeness of the product ranged from 7.33 to 7.83. The *lassi* obtained after 44.4% dilution obtained maximum score for overall acceptability. The dilution level (44.4%), was higher than percent dilution required for sweet *lassi* (36.5%). Thus salted *lassi* was favoured at thin consistency while sweet *lassi* was favoured when consistency was comparably richer.

4.3 STORAGE STUDY OF *DAHI* BLENDED WITH ELEPHANT FOOT YAM

Apart from the functionality and nutritional benefits provided by any food, its storage also influences the marketability of the food product. Therefore changes occurring in the *dahi* during storage were studied. *Dahi* containing EFY solids was kept in glass beakers covered with aluminium foil and polypropylene cups with lids, and stored at refrigeration temperature (6 ± 1°C) for 12 days. The stored product was examined at 3-days intervals for probable changes in its physical, sensory and textural properties.

4.3.1 Influence of storage on physical properties of *dahi*

The colour of yam-containing *dahi* was measured in terms of Whiteness Index (WI) (derived from Hunter L*, a* and b*). WI, was altered slightly but significantly during storage in both plain ($p \leq 0.05$) as well as elephant foot yam powder- blended *dahi* ($p \leq 0.01$). In plain *dahi*, WI increased from 85.83 to 86.05 and for a similar storage duration of yam-blended *dahi*, the WI increased 83.29 to 83.70. The colour was noticed to be maximum on 9th day of storage, after that a slight decrease in whiteness was noticed on 12th day of storage.

Measured by centrifugation, the water holding capacity (WHC) refers to the ability of gel to hold water, whilst syneresis (or 'wheying off') is defined as the shrinkage of the gel resulting concomitantly in expulsion of whey. WHC of *dahi* increased from 80.62 to 85.99% in plain *dahi* and from 79.14 to 86.81% in EFYS blended *dahi* (Table RD79). The increase was significant ($p \leq 0.01$) after 9 days in the former and 6 days in the latter. WHC increased continuously during the storage for 9 days after which it declined.

Syneresis followed an opposite trend as compared to WHC. With increasing storage time, syneresis increased, the increase being significant after 9 days in both plain and yam-added *dahi* ($p \leq 0.01$). In plain *dahi*, it increased from the initial 14.06% to 14.92% after 9 days and then decreased to 12% on 6th day; on 9th day an increase was observed in whey lost as the syneresis increased 14.92% which gradually subsided to 11.42% on 12th day of storage. Similarly, for *dahi* blended with EFYS the syneresis decreased from 17.72% to 13.28% on 6th day; a sudden increase was noted on 9th day as syneresis rose to 15.49% and then further reduced to 13.06% on 12th day of storage.

An initial decrease in syneresis for both *dahi*, was synonymous with corresponding increase in the WHC of the *dahi* samples. An increase in syneresis is generally due to higher solvation of the micellar system and to a more branched microstructure, which loses water when submitted to centrifugal force. A decreased syneresis points towards water binding ability of *dahi* (Remeuf *et al.* 2003). The decrease after 9th day could be attributed to high acid content at the end of the period (Lucey and Singh, 1998).

A decrease in whey separation during storage was also reported by Guzel-Seydim *et al.* (2005), Guven *et al.* 2005) and Isleten and Karagul-Yuceer (2006). Further perusal of the data indicates that during the initial phase of storage, WHC

was lower in yam-blended *dahi* when compared to plain *dahi* during the first half of the storage period following which it tended to be higher than WHC of plain *dahi*. The pH of yam dahi as well as plain dahi showed a declining trend apparently due to continued acid development and therefore increasing acid content of *dahi*. The pH of plain *dahi* declined from initial 4.41 to 3.58 after 12 days of storage.

A similar pattern was also seen in yam blended dahi which where the pH decreased from 4.52 to 3.67. Decrease in pH of *dahi* during storage was also observed by Senel *et al.* (2011), Espiraita-Santo *et al.* (2012) and Domagala *et al.* (2013).

4.3.2 Storage-induced changes in certain texture properties of *dahi*

The texture properties of *dahi* were measured in the terms of firmness, work of shear, work of adhesion and stickiness, using single compression test on a texture analyser. The texture of yogurt is a result of the development of a three-dimensional network of milk proteins due to aggregation of casein micelles together with denatured whey proteins through hydrophobic and electrostatic bonds (Paseephol *et al.* 2008).

Any change in the arrangement can influence the textural properties significantly. In the present study, the storage time did not significantly affect the firmness and work of shear values of plain or yam-added *dahi*. Firmness of plain *dahi* on 0th day of storage was 2.97 N, which started rising with storage time, though non-significantly and was found to be 3.19 N on 9th day of storage. The firmness value for yam *dahi* was lower than that of plain *dahi*. This probably might be due to the interference of psyllium-elephant yam solids on the formation of protein network (Meyer *et al.* 2011). The firmness of yam *dahi* showed an irregular pattern. It increased from 2.40 to 2.65 N from 0th day to 3rd day of storage, subsequently decreased to 2.38 N on 6th day and again increased to 2.57 N on 9th day. Finally after 12 days of storage, hardness decreased to 2.46 N.

Table RD79. Influence of storage time on whiteness index, water holding capacity, syneresis and pH of plain and elephant foot yam solids blended *dahi*

Storage period (days)	Physical parameters							
	Whiteness index		Water holding capacity (%)		Syneresis (%)		pH	
	Plain dahi	Yam dahi	Plain dahi	Yam dahi	Plain dahi	Yam dahi	Plain dahi	Yam dahi
0	85.83 ±0.02	83.29 ±0.06 ^a	80.62 ±0.24 ^a	79.14 ±0.58 ^a	14.06 ±0.88 ^{bc}	17.72 ±0.30 ^c	4.41 ±0.02 ^c	4.52 ±0.02
3	86.40 ±0.23	83.64 ±0.09 ^{ab}	83.43 ±1.03 ^{ab}	81.16 ±0.15 ^{ab}	12.19 ±0.34 ^{ab}	13.74 ±0.91 ^{ab}	3.94 ±0.02 ^b	4.13 ±0.01
6	86.18 ±0.06	83.79 ±0.03 ^b	84.06 ±0.28 ^{ab}	83.61 ±1.00 ^{bc}	12.00 ±0.70 ^{ab}	13.28 ±0.49 ^{ab}	3.84 ±0.00 ^b	3.84 ±0.03
9	86.40 ±0.06	83.94 ±0.10 ^b	85.59 ±0.91 ^b	86.81 ±0.42 ^d	14.92 ±0.27 ^c	15.49 ±0.40 ^{bc}	3.65 ±0.02 ^a	3.71 ±0.02
12	86.05 ±0.16	83.70 ±0.14 ^b	82.99 ±0.86 ^{ab}	83.98 ±0.30 ^c	11.42 ±0.29 ^a	13.06 ±0.05 ^a	3.58 ±0.01 ^a	3.63 ±0.01
F ratio	3.421*	8.12**	5.894**	26.19**	7.257**	14.56**	476.44**	436.34**

Mean ± SE from 3 replicates; means with different alphabetic superscripts in a column are significantly different as determined by Tukey's test; * p<0.05, **p<0.01

Increasing value of firmness during storage has been reported in gelatin added yoghurt by Fiszman *et al.* (1999) and Fiszman and Salvador (1999, 2004). The consequent decrease might be due to higher acidification after long duration of storage. For plain *dahi*, the work of shear value increased from 44.89 (0th day) to 46.17 N (9th day). The shear value further decreased to 38.44 N on 12th day of storage. On the contrary, yam *dahi* displayed decreasing value of work of shear till 6th day of storage. The value increased on 9th day of storage to 37.71 N. The value further decreased to 32.11 N on 12th storage day. Work of adhesion as determined instrumentally, decreased from 9.91 to 7.33 Ns while for yam *dahi*, work of adhesion value declined from 10.14 to 8.45 Ns. The decrease in both cases was statistically significant as analyzed by the analysis of variance. A slight increase in work of adhesion was noted on 9th day of storage in both *dahi* samples. The value of work of adhesion was higher for yam *dahi* when compared to plain *dahi* which certainly implied higher adhesiveness found in yam blended *dahi*. The cohesive nature of yam solids in combination with hydrocolloid could have contributed it enhanced value of work of adhesion. The stickiness followed trend similar to the work of adhesion. The stickiness value for plain *dahi* remained nearly same till 9th day of storage. A sharp decline was observed on 12th day of storage as the stickiness value reduced to 0.66 Ns. The yam *dahi* displayed almost similar trend, the stickiness remained same till 9 days of storage. A decline though minor was also noticed on 12th day.

4.3.3 Influence of storage period on sensory attributes of *dahi*

The *dahi* stored in refrigerated conditions was subjected to sensory evaluation on a 5-point scale. The appearance was scored to be 4.47 and 4.17 on the 0th day of storage and it declined gradually to 4.17 and 4.13 after 12th day of storage, for plain and yam *dahi*, respectively. The decrease was significant for plain *dahi* ($p \leq 0.05$) but not in yam-containing *dahi*. A decreasing trend in appearance score of stored goat milk's yoghurt was (also) observed by Domagala *et al.* (2013). Overall, the plain *dahi* had a higher appearance score during the entire storage period. The addition of yam solids and psyllium affected the appearance of *dahi* in an adverse manner, which was reflected in lower appearance score for yam *dahi*.

Table RD80. Texture parameters of plain and yam-added *dahi* during storage at 6±1°C

Storage period (days)	Texture attributes							
	Firmness (N)		Work of shear (Ns)		Work of adhesion (Ns)		Stickiness (N)	
	Plain dahi	Yam dahi	Plain dahi	Yam dahi	Plain dahi	Yam dahi	Plain dahi	Yam dahi
0	2.97 ±0.06	2.40 ±0.03	44.89 ±0.69	36.15 ±0.97	-9.91 ±0.47 ^a	-10.14 ±0.44 ^{ab}	-0.80 ±0.01 ^b	-0.78 ±0.03
3	3.05 ±0.08	2.65 ±0.18	44.97 ±0.49	35.96 ±1.19	-9.66 ±0.30 ^{ab}	-10.10 ±0.19 ^{ab}	-0.79 ±0.02 ^b	-0.77 ±0.02
6	3.18 ±0.09	2.38 ±0.16	45.89 ±0.91	35.16 ±1.68	-9.15 ±0.55 ^{ab}	-10.48 ±0.60 ^a	-0.83 ±0.02 ^b	-0.82 ±0.04
9	3.19 ±0.14	2.57 ±0.05	46.17 ±0.82	37.71 ±1.64	-9.18 ±0.65 ^{ab}	-10.60 ±0.06 ^a	-0.80 ±0.03 ^b	-0.78 ±0.02
12	2.75 ±0.26	2.46 ±0.16	38.44 ±3.86	32.11 ±1.44	-7.33 ±0.60 ^b	-8.45 ±0.48 ^b	-0.66 ±0.04 ^a	-0.71 ±0.05
F ratio	1.564	0.768	2.984	2.154	3.669 [*]	4.550 [*]	6.269 ^{**}	1.257

Mean ± SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * p<0.05, **p<0.01

The body and texture of both kinds of *dahi* (plain and yam) were found to be significantly affected during the storage. The score of plain *dahi* decreased from 4.07 (0th day of storage) to 3.43 (12th day of storage). During the same period, the body and texture score for yam blended *dahi* declined from 4.13 to 3.83. The observed reduction in body and texture score may be due to increased wheying-off (syneresis) caused by continued acidification during the storage.

Further, yam *dahi* was scored better for body and texture during the storage period. The flavour score changed in a significant ($p \leq 0.01$) manner during storage at refrigerated temperature. The flavour score for plain *dahi* declined from 4.43 (near 'very good') to 2.30 ('not very satisfactory'), after 12 days of storage. Likewise, the sensory flavour score for yam *dahi* decreased from 4.10 (0th day) to 2.50 (12th day). Both the types of *dahi* exhibited declining flavour score with storage period. The yam *dahi* was scored generally lower on sensory flavour score, apparently on account of the incorporation of yam. The declining flavour scores may be attributed to increasing acidity (sourness) due to unchecked production of acid during storage by culture organisms. Declining flavour score with storage period has been previously reported by Senel *et al.* (2011). The mouth-feel score as judged by sensory panellists also showed a declining trend with progressing storage period. The decline was found to be significant for both yam *dahi* ($p \leq 0.01$) as well as plain *dahi* ($p \leq 0.05$). The score for plain *dahi* dropped from 4.14 to 3.57 after the end of storage period. During similar period, the mouth-feel score of yam *dahi* declined from 3.77 (0th day) to 3.43 (12th day). Again, the mouthfeel score was generally lower for yam powder blended *dahi*, conceivably because of graininess rendered by yam solids and psyllium combination. The overall acceptability of the yam as well as plain *dahi* decreased with the advancing storage period. The decline was noted to be significant ($p \leq 0.01$) by analysis of variance for both the types of *dahi*. The acceptability score for plain *dahi* and yam *dahi* decreased in a manner similar to that observed for flavour reduction during storage. The gradual increase in acidity with time made the product increasingly sour and led to high reduction in flavour score. The flavour score for yam and plain *dahi* after 12 days of storage was 2.77 and 2.40, respectively. The acceptability of fermented milk foods has been reported to decrease with advancement of storage period owing to degradative actions of the culture-organisms (Khurana and Kanawjia, 2006; Cakmacki *et al.* 2012).

Table RD81. Sensory scores of stored plain and yam-containing *dahi*

Storage period (days)	Sensory attributes									
	Appearance score		Body and texture score		Flavour score		Mouth-feel score		Overall acceptability score	
	Plain dahi	Yam dahi	Plain dahi	Yam dahi	Plain dahi	Yam dahi	Plain dahi	Yam dahi	Plain dahi	Yam dahi
0	4.47 ±0.03 ^b	4.17 ±0.03	4.07 ±0.07 ^b	4.13 ±0.07 ^b	4.43 ±0.03 ^d	4.10 ±0.06 ^c	4.17 ±0.09 ^b	3.77 ±0.03 ^b	4.40 ±0.06 ^d	4.00 ±0.00 ^c
3	4.43 ±0.03 ^b	4.10 ±0.00	4.10 ±0.06 ^b	4.13 ±0.07 ^b	4.00 ±0.06 ^{cd}	3.87 ±0.03 ^c	4.10 ±0.06 ^b	3.77 ±0.03 ^b	3.87 ±0.07 ^c	3.90 ±0.06 ^c
6	4.43 ±0.03 ^b	4.13 ±0.03	3.87 ±0.12 ^b	4.03 ±0.03 ^{ab}	3.70 ±0.17 ^{bc}	3.53 ±0.03 ^b	3.90 ±0.12 ^{ab}	3.60 ±0.00 ^{ab}	3.33 ±0.09 ^b	3.37 ±0.13 ^b
9	4.40 ±0.06 ^{ab}	4.20 ±0.06	3.47 ±0.09 ^a	4.00 ±0.06 ^{ab}	3.20 ±0.15 ^b	3.23 ±0.12 ^b	4.00 ±0.12 ^{ab}	3.70 ±0.00 ^b	3.23 ±0.12 ^b	3.10 ±0.06 ^{ab}
12	4.17 ±0.09 ^a	4.13 ±0.03	3.43 ±0.07 ^a	3.83 ±0.03 ^a	2.30 ±0.06 ^a	2.50 ±0.06 ^a	3.57 ±0.15 ^a	3.43 ±0.12 ^a	2.40 ±0.06 ^a	2.77 ±0.15 ^a
F ratio	5.115*	1.083	14.887**	5.269*	54.973**	83.167**	4.698*	14.833**	83.967**	30.146**

Mean ± SE from 3 replicates; means with different alphabetic superscript in different columns are significantly different as determined by Tukey's test; * p<0.05, **p<0.01

4.4 CONSUMER RESPONSE STUDY OF YAM-DAHI

The consumer response of newly developed food product could give us about the measure of worthiness of the product. It could be of immense use, if we want to know about the market potential of the product.

To know about the consumer acceptability of yam *dahi*, consumer response study was conducted using consumer appraisal form (Annexure-8).

The yam dahi was packed in PS cups and served a refrigerated temperature to the consumers (both male and female). The frequency distribution of consumer acceptability is presented in Table RD 82. Out of 104 respondents of both sexes, (age group: 20-55 years), 20 (19.23%) considered the yam dahi to be excellent for consumption. Thirty five percent consumers rated dahi to be very good, while almost 31% consumers judged it to be good. Only 14% of the respondents perceived dahi to be fair. It was thus evident that yam dahi showed good acceptability rating with almost 85% consumers showing their preference for it.

Table RD82. Consumer response for yam *dahi*

Degree of liking	No. of consumer respondents	Overall Percentage
Excellent	20	19.23
Very Good	37	35.58
Good	32	30.77
Fair	15	14.42
Total	104	100

Further, consumers were also asked whether they would buy dahi if its cost is comparable with conventional dahi. Almost 90% consumers were willing to purchase yam dahi at competitive rates instead of conventional dahi. Thus, it could be presumed that yam dahi has good market potential.

4.5 COST OF PRODUCTION FOR YAM-DAHI

Cost of product plays an important role in marketing of the food products. With an aim to market yam enriched dahi, cost of its production was calculated taking into consideration that production occurs in plant.

4.5.1 Basic assumptions for cost estimation

To determine the cost of production of yam dahi, following basic assumptions were made:

- The plant capacity would be 7.5 lakh litre per annum.
- The plant would be operated in two shifts, and 300 days in a year.
- The finished product would be packaged in 100 g size cups.
- The processing losses were presumed to be 0.5%.

4.5.2 Detailed break-up of total cost of yam *dahi*

The estimated price of different equipments and machinery necessary for the production are described in Annexure-9.

The cost of equipment for product manufacture was estimated to be 11045000 and annual depreciation rate workout to be Rs. 617250. Thus, total cost of equipment was calculated to Rs. 10427750.

The requirements in terms of building and equipments and their approximate costs at current rates, along with the annual depreciation, are presented in Annexure-9. The cost of raw materials required to manufacture 750000 L of product is given in Annexure-10. The cost of various ingredients was calculated according to the prevailing market cost at the time of study and was estimated as Rs. 33912500.

The cost of production was estimated to be Rs. 73.70 per litre of yam *dahi*, as per the prevailing raw material and manufacturing expenses. Hence, from the consumer response study and cost estimation it is expected that the yam dahi could have a good market potential both cost-wise and with respect to consumer preference.

Table RD83. Detailed break-up cost for the manufacture of yam *dahi*

S. No.	Cost components	(Qty/y)	Cost (lakhs per annum)
(a)	Direct Cost		
(i)	Raw Material		339.12
(ii)	Operating labour and supervision		
	Manager (@ Rs 35000 p.m.)	1 No.	4.2
	Manager Production & Quality Control (@ Rs 25000 p.m.)	1 No.	3
	Supervisors (@ Rs17000 p.m.)	2 No.	4.08
	Plant operator (@ Rs 9000 p.m.)	3 No.	3.24
	Lab. Tech. (@ Rs.11000 p.m.)	2 No.	2.6
	Labour (@ Rs 6000 p.m.)	4 No.	2.8
	Sub Total		19.92
(iii)	Power and Utility		
	Steam (@ Rs 800/1,000 kg.)	120000	0.96
	Power (@Rs 5.00/kwh)	96 900	4.84
	Water (@ Rs 10.00/1,000 L)	20 Lakhs/L	0.2
	Sub Total		6.00
(iv)	Laboratory charges @ 0.2% of cost of raw material		0.52
(v)	Cleaning and sanitizing material @ 1.0% of cost of raw material		2.81
	Total (a)		368.37
(b)	Fixed Charges		
	Depreciation on capital investment		6.18
	Insurance and Taxes @ 2% of capital investment		2.02
	Interest on investment@ 15% per annum		16.56
	Total (b)		24.76
	Product cost = (a+b)		393.13
	Packaging material cost		30
A.	Manufacturing cost		423.13
B.	Overhead cost @ 15% of manufacturing cost		63.47
C.	Total cost= (A+ B) (660000 kg)		486.60
	Total cost /L		73.70

*Qty- quantity; p.m.- per month

CHAPTER – 5

Summary and Conclusions

5. SUMMARY AND CONCLUSION

Nowadays, consumers are more conscious of fact that diet is an essential factor in maintaining good health. Therefore, consumers are gravitating towards foods that offer additional benefits beyond that provided by conventional food. World Health Organization (WHO) has already identified nutrition as a significant and manageable determinant of chronic disease, stressing the need for a shift in nutrient intake towards 'healthier' foods (WHO, 2002). These foods, also called as 'Functional Foods', are intended to be consumed as part of a normal diet. These foods contain ingredients that have the potential to enhance human health or reduce the risk of disease beyond basic nutritional functions. The remarkable growth of the functional foods and natural health products is somewhat linked to consumers' increasing interest in eating these healthier foods.

Elephant foot yam, (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is an important but underutilized vegetable tuber crop of family Araceae (Aroid). It is good source of starch, minerals (calcium, phosphorus, iron, potassium) and vitamins (vitamin A, thiamine, niacin, riboflavin). Apart from that, it also contains wide range of phytochemicals i.e. phenols, flavonoids, and glycosides. Its medicinal properties are well recognized in Ayurveda. The presence of oxalates, which are responsible for acrid sensation in throat and mouth on consumption of yam and lack of knowledge amongst people regarding its value and processing, has contributed towards gross underutilization of elephant foot yam. Dairy products are among the most preferred options to be formulated into functional foods by incorporating non-dairy bioactive components. The merging of plant and dairy based foods have given rise to 'hybrid' dairy products which offer health, flavor and convenience. The fermented foods are an excellent medium to generate an array of products that fit into the consumer demand for health based foods. Fermented dairy products can serve as carrier medium, through which elephant foot yam can be consumed and its various functional and therapeutic benefits can be made use of. Also, incorporation of elephant foot yam as a source of starch-it contains 17% starch--in these foods can enhance its appeal and palatability through textural modifications, and thereby, have a positive impact upon its consumption. The present study was designed to incorporate

elephant foot yam as a functional ingredient in *dahi* and *lassi*. The findings of the present study are summarized here under-

5.1 Effect of alkaline, saline and acidulated saline pre-soaking followed by cooking treatment of elephant foot yam on its acidity and/ or oxalate

Elephant foot yam was subjected to alkaline, saline and acidulated saline pre-soaking treatments followed by cooking, to mitigate the problem of acidity and/ or oxalate.

The oxalate contents of EFY after different pre-soaking treatments, namely, alkali, saline and acidulated saline, were noticed to be 91.87-94.61, 94.60-98.58 and 94.61-96.43 mg/100 g, respectively. The three pre-soaking treatments combined with cooking, did not affect the oxalate content significantly. For these treatments, the hand sensed acidity scores were found to be 0.45-1.03, 1.05-1.68 and 1.05-1.45, respectively. The alkaline treatment reduced the acidity sensation significantly ($p \leq 0.05$), while the other two combinations increased the acrid sensation highly significantly ($p \leq 0.01$); though significant correlation could not be observed between acidity response and reduction in the oxalate content of EFY. The oxalate reduction with alkali treatment was observed to be concentration dependent. Increased alkali concentration decreased the acidity score of EFY paste significantly ($p \leq 0.05$). The whiteness index of EFY paste was reduced highly significantly ($p \leq 0.01$) by alkali treatment and the maximum WI was obtained for acidulated saline treated EFY. For all the treatments, acidity in yam-milk mix was not perceived; the acidity score varied from 6.5 to 7.5 on 9 point hedonic scale. The sedimentation in yam milk mix varied from 0.19 to 0.23 per gram of yam-milk mix.

5.2 Effect of warm alkali pre-soaking treatment of elephant foot yam on its oxalate content

The alkali pre-soaking treatment applied to EFY certainly appeared to be an effective strategy in combating the problem of high oxalate content associated with EFY. However, the alkali pre-soaking treatment caused appreciable discoloration/ darkening of the yam as observed in terms of whiteness index ($p \leq 0.01$), and there was no significant effect on the sensory acidity score. Thus it was concluded that soaking in sodium hydroxide solution altered sensory attributes of yam in an adverse manner. The blandness, which is closely related

with the edibility of EFY, was hampered unfavourably and the yam was rejected by sensory panellists.

5.3 Effect of pre-soaking in NaHCO₃ solution followed by cooking of elephant foot yam upon its acidity

The EFY paste obtained from alkali pre-soaked and alkali cooked yam had an offensive odour, coupled with a mushy and pulpy texture. The structural disintegration of the yam cubes during the process of soaking and cooking caused the cubes to become soft and pulpy. The combination of sodium bicarbonate pre-soaking and cooking tried affected the yam in manner similar to alkali soaking. The yam cubes were rejected sensorially.

5.4 Effect of cooking of elephant foot yam in boiling water on its oxalate content

Cooking of EFY for different durations caused considerable changes in the various phytochemicals present in it. The effect of cooking was also significant the sensory attributes of cooked EFY paste (colour and acidity) and cubes (softness). Further, boiling of the yam for initial 10 min significantly ($p \leq 0.01$) decreased the oxalate content, both soluble and insoluble. However, reduction was non-significant when yam was cooked for more than 10 minutes. Similar trends were noticed in the cooking-mediated reduction in sensorial acidity score.

Accordingly, 10 min cooking as such was considered to be sufficient for reduction of oxalates. Hence, 10 min boiling was resorted to for cooking elephant foot yam in further studies.

5.5 Standardization of drying of elephant foot yam

The drum drying of the slurry was observed to be non-feasible, because of lack of film forming ability of the slurry. Spray drying of yam slurry was hindered by blockage of atomizer nozzle and excessive sticking of the process material on the walls of the spray dryer.

The hot-air drying was carried out at different temperatures (50°C, 60°C and 70°C) till the yam paste acquired a brittle consistency. Colour of the dried yam was influenced in a significant manner by the drying temperature. The whiteness index (66.33 (70°C) to 71.15 (50°C)) showed a highly significant ($p \leq 0.01$) decline with increasing drying temperature. The bulk density showed an increasing trend with increasing drying temperature. The true density was not affected by the drying temperature. The increased drying temperature led to

increased WAI of the powder while WSI of EFY powder decreased significantly ($p \leq 0.05$). OAI showed a significant ($p \leq 0.05$) declining trend with increasing drying temperature. The drying treatments caused non-significant reduction in oxalate content. The phenolic content in water and methanolic extract of powder decreased with drying temperature, but the DPPH and ABTS values decreased for water extract and increased for methanolic extract.

On account of better sensory acceptability and low setback viscosity, the powder obtained after drying elephant yam at 60°C was found to be suitable for its addition in *dahi* and *lassi*. Powder obtained from 10 min cooked elephant foot yam dried at 60°C in a tray dryer, was blended into milk for the preparation of *dahi*. The powder possessed following pasting attributes: peak viscosity, 548 mPa.s; breakdown viscosity, 80 mPa.s; setback viscosity, 380 mPa.s; pasting temperature, 94.1°C and had a whiteness index of 69.05.

5.6 *Dahi* and *lassi* blended with elephant foot yam

Yam powder, along with various levels of psyllium and milk fat was studied for *dahi* making using Box-Behnken design of Response Surface Methodology. A response surface methodology (RSM) experiment was designed incorporating the elephant foot yam solids (EFYS), psyllium (PSY) and milk fat (MF) in the range of 0.5-2.0%, 0.1-0.3% and 1.5-4.5%, respectively as process variables.

The optimal levels of the three ingredients viz. milk fat, elephant foot yam solids and psyllium solids were worked out to be 2.1 %, 1.25 % and 0.1 %, respectively. Yam *dahi* was prepared with the suggested formulation to check its validity with the predicted score. All the quality parameters of the suggested above formulation were in good agreement with the predicted scores. The *dahi* obtained with above formulation was sensorially well accepted by consumers.

The optimized yam-blended *dahi* had 13.30% TS including 5.54% carbohydrates, 3.8% protein, 3.1% fat, 0.13% fibre and 0.86% ash. The total phenolic content, DPPH, ABTS activity of water and methanolic extract per g yam *dahi*, on dry matter basis, were 11010.8 µg GAE, 27.23 mM TEAC, 85.64 mM TEAC and 21859.57 µg GAE, 105.21 mM TEAC, 54.42 mM TEAC, respectively.

The optimized *dahi* was further processed to *lassi*, both sweet and salted. The rose-flavoured sweet *lassi* with dilution level of 37.5% (600 g water per kg *dahi*) and salted *lassi* with dilution level of 44.4% (800 g water per kg *dahi*) was sensorially most preferred.

The dilution level (44.4%) for salted *lassi* was higher than percent dilution (36.5%) required for sweet *lassi*. Thus salted *lassi* was favoured at thinner consistency, while sweet *lassi* was favoured when consistency was comparably richer.

5.7 Storage study of yam containing *dahi*

Dahi containing EFY solids, along with control (plain *dahi*) was subjected to storage analysis at refrigeration temperature ($6\pm 1^{\circ}\text{C}$) for 12 days. The stored product was examined at every three days intervals for probable changes in its physical, sensory and textural properties. The sensory scores (particularly flavour and overall acceptability score) of yam and plain *dahi* decreased constantly throughout the storage, and the samples were disliked by sensory panellists on 12th day of storage. The storage life of yam blended *dahi* was found similar to plain *dahi*.

5.8 Consumer response and cost of production of the product

Out of 104 respondents of both sexes, (age group: 20-55 years), 20 (19.23%) considered the yam *dahi* to be excellent for consumption. Thirty five percent consumers rated *dahi* to be very good, while almost 31% consumers judged it to be good. Only 14% of the respondents perceived *dahi* to be fair. It was thus evident that yam *dahi* showed good acceptability rating with almost 85% consumers showing their preference for it. The cost of yam *dahi* was calculated on the basis of setting up a new plant with a capacity of producing 7.5 lakh litre *dahi* per annum. The total cost of equipments was calculated to be Rs. 10427750, and the cost of various ingredients according to the prevailing market cost was estimated to be Rs. 33912500. The cost of production was estimated to be Rs. 73.70 per litre of yam *dahi*.

5.9 Conclusions

Based on summary presented above, following conclusions were drawn-

- The cooking of elephant foot yam in boiling water for 10 min could be used to reduce oxalate and acidity content.
- Due to better sensory acceptability and low setback viscosity, the elephant foot yam tray dried at 60°C was best suited for its addition in *dahi* and *lassi*.

- *Dahi* could be fortified at level of 1.25% yam solids and 0.15% psyllium for sensorially acceptable attributes.
- The incorporation of elephant foot yam powder, resulted in sensorially well acceptable low fat *dahi* having desired textural attributes and enhanced phytochemical attributes.

5.10 Suggestions for future research

Based on the results of the present study, following suggestions are made for further research –

- Various other food processing technologies like microwave treatment, HPP, ohmic heating etc. can be tried to reduce oxalate content in food products.
- Bio-actives present in yam can be isolated and added in various foods
- Different preservation methodologies viz. addition of bio-preservatives, non-thermal interventions can be used to improve the shelf-life of yam *dahi*
- Animal studies should be undertaken to know about the efficacy of bio-active compounds
- Incorporation of elephant foot yam in various dairy foods can be studied.

Bibliography

BIBLIOGRAPHY

- Abbasi, H., Mousavi, M. E., Eshani, M. R., D-Jomea, Z. E., Vaziri, M., Rahimi, J. and Aziznia, S. (2009). Influence of starter culture type and incubation temperatures on rheology and microstructure of low fat set yoghurt. *International Journal of Dairy Technology*, **62**(4): 549-555.
- Abera, S., and Rakshit, S. K. (2003). Comparison of physicochemical and functional properties of cassava starch extracted from fresh root and dry chips. *Starch/ Starke*, **55**: 287–296.
- Aboubakar, Njintang, N. Y., Scher, J. and Mbofung, C. M. F. (2009). Texture, microstructure and physicochemical characteristics of taro (*Colocasia esculenta*) as influenced by cooking conditions. *Journal of Food Engineering*, **91**: 373–379.
- Acharya, S. M., Misra, R. S. and Nedunchezian, M. (2005). Some value added products from *Amorphophallus* tubers. *Proceedings NSRTC-2*, pp. 61-64.
- Aguilera, J. M. and Kessler, H. G. (1989). Properties of mixed and filled type dairy gels. *Journal of Food Science*, **54**: 1213–1217.
- Aguilera, Y., Estrella, I., Benitez, V., Estebana, R. M. and Martín-Cabrejas, M. A. (2011). Bioactive phenolic compounds and functional properties of dehydrated bean flours. *Food Research International*, **44**: 774–780.
- Ahmed, M., Akter, M. S. and Eun, J. (2010). Peeling, drying temperatures, and sulphite-treatment affect physicochemical properties and nutritional quality of sweet potato flour. *Food Chemistry*, **121**: 112–118.
- Ajandouz, E. H. and Puigserver, A. (1999). Non-enzymatic browning reaction of essential amino acids: Effect of pH on caramelization and Maillard reaction kinetics. *Journal of Agricultural and Food Chemistry*, **47**: 1786–1793.
- Ajandouz, E. H., Tchiakpe, L. S., Dalle-Ore, F., Benajiba, A. and Puigserver, A. (2001). Effect of pH on caramelization and Maillard reaction kinetics in fructose-lysine model systems. *Journal of Food Science*, **66**: 926–931.
- Akhtar, M. S., Israr, B., Bhatti, N. and Ali, A. (2010). Effect of cooking on soluble and insoluble oxalate contents in selected Pakistani vegetables and beans. *International Journal of Food Properties*, **14**(1): 241-249.
- Akissoe, N., Hounhouigan, J., Mestres, C. and Nago, M. (2003). How blanching and drying affect the colour and functional characteristics of yam (*Dioscorea cayenensis-rotundata*) flour. *Food Chemistry*, **82**: 257-264.
- Alakali, J. S., Okonkwo, T. M. and Lordye, E. M. (2008). Effect of stabilizers on the physico-chemical and sensory attributes of thermized yoghurt. *African Journal of Biotechnology*, **7**(2): 158-163.
- Alberti, A., Zielinski, A. A. F., Zardo, D. M., Demiate, I. M., Nogueira, A. and Mafra, L. I. (2014). Optimisation of the extraction of phenolic compounds from apples using response surface methodology. *Food Chemistry*, **149**: 151–158.

- Albihn, P. B. E and Savage, G. P. (2001). The effect of cooking on the location and concentration of oxalate in three cultivars of New Zealand-grown oca (*Oxalis tuberosa* Mol). *Journal of the Science of Food and Agriculture*, **81**: 1027–1033.
- Alister, H. (1990). *Aroids of Papua New Guinea*. CRI Publication No.10. Christensen Research Institute, Madang. pp 43.
- Allison, M. J., Cook, H. M., Milne, D. B., Gallagher, S. and Clayman, R. V. (1986). Oxalate degradation by gastrointestinal bacteria from humans. *Journal of Nutrition*, **116**(3): 455-60.
- Allison, M. J., Dawson, K. A., Mayberry, W. R. And Foss, J. G. (1985). *Oxalobacter formigenes* gen. Nov., sp. Nov.: oxalate-degrading anaerobes that inhabit the gastrointestinal tract. *Archives of Microbiology*, **141**(1): 1-7.
- Allothman, M., Bhat, R. and Karim, A. A. (2009). Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. *Food Chemistry*, **115**(3): 785-788.
- Alting, A. C., Velde, F., Kanning, M. W., Burgering, M., Mulleners, L., Sein, A. and Buwalda, P. (2009). Improved creaminess of low-fat yoghurt: The impact of amylo-maltase-treated starch domains. *Food Hydrocolloids*, **23**: 980–987.
- Amatayakul, T., Sherkat, F. and Shah, N. P. (2006). Syneresis in set yogurt as affected by EPS starter cultures and levels of solids. *International Journal of Dairy Technology*, **59**(3): 216-221.
- Amaya-Llano, S. L., Martinez-Alegri, A. L, Zazueta-Morales, J. J., and Martinez-Bustos, F. (2008). Acid thinned jicama and maize starches as fat substitute in stirred yogurt. *LWT*, **41**: 1274–1281.
- Anderson, R. A., Conway, H. F. and Peplinski, A. J. (1970). Gelatinization of corn grits by roll cooking, extrusion cooking and steaming. *Starch – Stärke*, **22**(4): 130–135.
- Anese, M., Nicoli, M. C. and Lerici, C. R. (1994). Influence of pH on the oxygen scavenging properties of heat-treated glucose/glycine systems. *Italian Journal of Food Science*, **3**: 339–343.
- Angayarkanni, J., Ramkumar, K. M., Poornima, T. and Priyadarshini, U. (2007) Cytotoxic activity of *Amorphophallus paeoniifolius* tuber extracts in vitro. *American- Eurasian Journal of Agriculture and Environment Science*, **2**(4): 395-398.
- Anonymous (2010). www.ayurvedakalamandiram.com/vegetable, accessed on 16 October 2010.
- Antai, S. P. and Obong, U. S. (1992). The effect of fermentation on the nutrient status and some toxic components of *Ipocacia manni*. *Plants Food for Human Nutrition*, **42**: 219-224.
- AOAC. (2000). Official methods of analysis (17th ed.). Association of Official Analysis Chemists (AOAC), Washington, DC, USA

- Aremu, C. Y. and Abara, A. E. (1992). Hydrocyanate, oxalate, phytate, calcium and zinc in selected brands of Nigerian cocoa beverage. *Plant Foods for Human Nutrition*, **2**: 231–237.
- Ares, G., Gonçalves, D., Pérez, C., Reolón, G., Segura, N., Lema, P. and Gámbaro, A. (2007). Influence of gelatin and starch on the instrumental and sensory texture of stirred yogurt. *International Journal of Dairy Technology*, **60**: 263–269.
- Arora, S. K. (2006). Functionality enhancement of selected milk foods via dietary fiber incorporation. PhD thesis, NDRI, Karnal.
- Asolkar, L. V., Kakkar, K. K. and Chakre, O. J. (1992). Glossary of Indian medicinal plants with active principle, Part 1. *Publication and Information Directorate*, **59**.
- Atici, T., Khawar, K., Ozel, C.A., Katircioglu, H. and Ates, M. A. (2008). Use of psyllium (isubgol) husk as an alternative gelling agent for the culture of 600 prokaryotic microalgae (Cyanobacteria) *Chroococcus limneticus* Lemmermann and eukaryotic green microalgae (Chlorophyta) *Scenedesmus quadriQ9cauda* (Turpin) *Brebisson*. *African Journal of Biotechnology*, **7**: 1163-1167
- Atwell, W. A., Hood, L.F., Lineback, D. R., Varriano-Marston, E. and Zobel, H. F. (1988). The terminology associated with basic starch phenomena. *Cereal Foods World*, **33**: 306–311.
- Ayernor, G. S. (1985). The Yam (*Dioscorea*) Starches. In: Advances in Yamresearch. 1st ed. Godson Osuji. Anambra State University of Technology Publishers. Nigeria. pp. 79-88.
- Bahorun, T., Luximon-Ramma, A., Crozier, A. and Aruoma, O. I. (2004). Total phenol, flavonoid, pro-anthocyanidin and vitamin C levels and antioxidant activities of Mauritian vegetables. *Journal of the Science of Food and Agriculture*, **84**: 1553–1561.
- Bakr, A. A. and Gawish R. A. (1997). Trials to reduce nitrate and oxalate content in some leafy vegetables2. Interactive effects of manipulating the soil nutrient supply, different blanching media and preservation methods followed by cooking process. *Journal of the Science of Food and Agriculture*, **73**: 169-178.
- Bala, N., Wilson, B., Manju, V. S. and Sundaresan, S. (2007). Pharmacological properties of *Amorphophallus paeoniifolius*. In: Padmaja G, Premkumar T, Edison S, Bala N (eds) Root and tuber crops: proceedings of the national seminar on achievements and opportunities in post harvest management and value addition in root and tuber crops (NSTRC 2). Central Tuber Crops Research Institute, Thiruvananthapuram, pp. 325–328.
- Banks, S. J. (1963). *The Endeavour Journal of Joseph Banks 1768-1771*. eds. Beaglehole, J. C., Angus and Robertson. 2nd edn., Vol. **2**. Sydney, Australia, pp. 85.

- Becker, T. and Puhan, Z. (1981). Effect of different processes to increase the milk solids non-fat content on the rheological properties of yogurt. *Milchwissenschaft*, **44**: 626–629.
- Belviso, S., Ghirardello, D., Giordano, M., Ribeiro, G. R., Alves, J. S., Parodi, S., Risso, S. and Zeppa, G. (2013). Phenolic composition, antioxidant capacity and volatile compounds of licuri (*Syagrus coronata* (Martius) Beccari) fruits as affected by the traditional roasting process. *Food Research International*, **51**(1): 39-45.
- BeMiller, J. N. and Whistler, R. L. (1997). Carbohydrate. In R. Fennema Owen (Ed.), *Food chemistry*, Columbus, Ohio State, pp. 157–223.
- Benjakul, S., Visessanguan, W., Phongkanpai, V. and Tanaka, M. (2005). Antioxidative activity of caramelization products and their preventive effect on lipid oxidation in fish mince. *Food Chemistry*, **90**: 231–239.
- Bernhart, S. and Schlich, E. (2005). Impact of different cooking methods on food quality: Retention of lipophilic vitamins in fresh and frozen vegetables. *Journal of Food Engineering*, **17**: 327–333.
- Bhandari, M. R. and Kawabata, J. (2006). Cooking effects on oxalate, phytate, trypsin and α -amylase inhibitors of wild yam tubers of Nepal. *Journal of Food Composition and Analysis*, **19**: 524–530.
- Biliaderis, C. G. (2009). Structural Transitions and Related Physical Properties of Starch. In: *Starch: Chemistry and Technology*. Whistler, R. L. and Paschall, E. F. (eds.). Academic Press. New York, USA. pp. 293-372.
- Borah, P., Saikia, J. and Narzary, B. D. (2008). Status of elephant foot yam cultivation in Assam. In Palaniswami, M.S. *et al.*, ed., National Seminar on *Amorphophallus*: innovative technologies, July 19-20, 2008, Patna, Bihar-abstract book, status papers and extended summary, pp. 55-57.
- Bradbury, J. H. and Hammer, B. C. (1990). Comparative study of proteinase inhibitors in tropical root crops and survey of allelochemicals in the edible aroid. *Journal of Agricultural and Food Chemistry*, **38**: 1448–1453.
- Bradbury, J. H. and Holloway, W. D. (1988). Chemistry of Tropical Root Crops: *Significance for Nutrition and Agriculture in the Pacific*. Australian Centre for International Agricultural Research, Canberra, Australia, pp. 110-119.
- Bradbury, J. H. and Holloway, W. D. (1988). *Chemistry of Tropical Root Crops: Significance for Nutrition and Agriculture in the Pacific*. Australian Centre for International Agricultural Research, Canberra, Australia, pp. 51-68.
- Bradbury, J. H. and Nixon, R.W. (1998). The acidity of raphides from the edible aroids. *Journal of the Science of Food and Agriculture*, **76**: 608-616.
- Brand Williams, W., Cuvelier, M. and Berset, C. (1995). Use of free radical method to evaluate antioxidant activity. *Lebensm Wiss and Technology*, **28**: 25-30.
- Brighenti, M., Govindasamy-Lucey, S., Lim, K., Nelson, K. and Lucey, J.A. (2008). Characterization of the rheological, textural, and sensory properties

- of samples of commercial US cream cheese with different fat contents. *Journal of Dairy Science*, **91**(12): 4501–4517.
- Brown, M. W. (1995). Quality Standard and Marketing of Selected South Pacific Root Crops. The Publication Office, Institute for Research, Extension and Training in Agriculture (IRETA). The University of the South Pacific, School of Agriculture, Alafua Campus, Apia, Samoa.
- Bruzzone, F. Ares, G. and Gimenez, A. (2013). Temporal aspects of yoghurt texture perception. *International Dairy Journal*, **29**(2): 124–134.
- Cakmakci, S., Cetin, B., Turgut, T., Gurses, M. and Erdogan, A. (2012). Probiotic properties, sensory qualities, and storage stability of probiotic banana yogurts. *Turkish Journal of Veterinary and Animal Science*, **36**(1): 231-237.
- Campbell-Platt, G. (1987). Fermented foods of the world – a dictionary and guide. London, Butterworths. ISBN: 0-407-00313-4
- Campieri, C., Campieri, M., Bertuzzi, V., Swennen, E., Matteuzzi, D., Stefoni, S., Pirovano, F., Centi, C., Ulisse, S., Famularo, G. and De Simone, C. (2001). Reduction of oxaluria after an oral course of lactic acid bacteria at high concentration. *Kidney International*, **60**: 1097–1105.
- Cardoso, C., Mendes, R. and Nunes, M. L. (2007). Effect of transglutaminase and carrageenan on restructured fish products containing dietary fibres. *International Journal of Food Science and Technology*, **42**: 1257–1264.
- Carpenter, J. R. and Steinke, W. E. (1983). Animal feed. In: Wang, J. K. ed., Taro: a review of *Colocasia esculenta* and its potentials. University of Hawaii Press, Honolulu, Hawaii, USA, pp. 269-300.
- Catherwood, D. J., Savage, G. P., Mason, S. M., Scheffer, J. J. C. and Douglas, J. A. (2007). Oxalate content of cormels of Japanese taro (*Colocasia esculenta* (L.) Schott) and the effect of cooking. *Journal of Food Composition and Analysis*, **20**(3-4): 147-151.
- Chai, W. and Liebman, M. (2004). Assessment of oxalate absorption from almonds and black beans with and without the use of an extrinsic label. *Journal of Urology*, **172**: 953-957.
- Chai, W. and Liebman, M. (2005). Effect of different cooking methods on vegetable oxalate content. *Journal of Agriculture and Food Chemistry*, **53**: 3027-3030.
- Chandan, R. C. (1999). Enhancing market value of milk by adding cultures. *Journal of Dairy Science*, **82**: 2245-2256
- Chattopadhyay, A., Saha, P., Pal, S., Bhattacharya, A. and Sen, H. (2010). Quantitative and qualitative aspects of elephant foot yam. *International Journal of Vegetable Science*, **16**: 73-84.
- Chauhan, G. S. and Bains, G. S. (1988). Effect of some extruder variables on physico-chemical properties of extruded rice–legume blends. *Food Chemistry*, **27**(3): 213–224.

- Chiang, P. and Luo, Y. (2007). Effects of pressurized cooking on the relationship between the chemical compositions and texture changes of lotus root (*Nelumbo nucifera* Gaertn.). *Food Chemistry*, **105**(2): 480-484.
- Cho, Y. H., Lucey, J. A. and Singh, H. (1991). Rheological properties of acid milk gels as affected by the nature of the fat globule surface material and heat treatment of milk. *International Dairy Journal*, **9**: 537–545.
- Cleveland, D. A. and Soleri, D. (1991). An ecological, nutritional and social approach to small scale house-holds food production. Food from Dry land Gardens, Centre for People, Food, and Environment (CPFE), USA. Pp 26-29.
- Cobos, A., Horne, D. S. and Muir, D. D. (1995). Rheological properties of acid milk gels. I. Effect of composition, process, and acidification conditions on products from recombined milks. *Milchwissenschaft*, **50**: 444–447.
- Cohen, M. F., Sakihama, Y. and Yamasaki, H. (2001). Roles of plant flavonoids in interactions with microbes: from protection against pathogens to mediation of mutualism S.G. Pandalai (Ed.), *Recent research developments in plant physiology*, Vol. 2, Research Signpost, Trivandrum, pp. 157–173.
- Collins, J. L., Ebah, C. B., Mount, J. R., Demott, B. J. and Draughon, F. A. (1991). Production and evaluation of milk-sweet potato mixtures fermented with yoghurt bacteria. *Journal of Food Science*, **56**(3): 685-688.
- Connor, H. E. (1977). The poisonous plants in New Zealand. Government Printer, Wellington, New Zealand.
- Cordenunsi, B. R., Menezes, E. W. D., Genovese, M. I., Colli, C. L., Souza, A. G. A. D. and Lajolo, F. M. (2004). Chemical composition and glycemic index of Brazilian pine (*Araucaria angustifolia*) seeds. *Journal of Agricultural and Food Chemistry*, **52**: 3412- 3416.
- Cox, P. A., Sperry, L. R., Tuominen, M. and Bohlin, L. (1989). Pharmacological activity of the Samoan ethnopharmacopoeia. *Economic Botany*, **43**(4): 487-497.
- CTCRI. (2010). CTCRI News. Vol. **27**(4). Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.
- Cui, B., Lu, Y., Tan, C., Wang, G. and Li, G. (2014). Effect of cross-linked acetylated starch content on the structure and stability of set yoghurt. *Food Hydrocolloids*, **35**: 576-582.
- Das, D., Mondal, S., Roy, S. K., Maiti, D., Bhunia, B., Maiti, T. K. and Islam, S. S. (2009). Isolation and characterization of a heteropolysaccharide from the corm of *Amorphophallus campanulatus*. *Carbohydrate Research*, **344**(18): 2581-2585.
- Daugherty, A. L. and Mrsny, R. J. (1999). Transcellular uptake mechanisms of the intestinal epithelial barrier Part one. *Pharmaceutical Science and Technology Today*, **2**: 144–151.
- Davey, M. W., Van-Montagu, M., Inze, D., Sanmartin, M., Kanellis, A., Smirnoff, N., Benzie, I. J. J., Strain, J. J., Favell, D. and Fletcher, J. Plant L-ascorbic

- acid: Chemistry, function, metabolism, bioavailability and effects of processing. *Journal of the Science of Food and Agriculture*, **80**: 825–860.
- De, S. (1980). *Oulines of Dairy Technology*. Oxford University Press, New Delhi, India, pp: 463-464.
- De, S., Dey, Y. N. and Ghosh, A. K. (2010). Anti-inflammatory activity of methanolic extract of *Amorphophallus paeoniifolius* and its possible mechanism. *International Journal of Pharma and Biosciences*, **1**(3): 1-8.
- Dey, Y. N., De, S. and Ghosh, A. K. (2010). Evaluation of analgesic activity of methanolic extract of *Amorphophallus paeoniifolius* tuber by tail flick and acetic acid induced writhing response method. *International Journal of Pharma and Biosciences*, **1**(4): 662-668
- Ding, Q. B., Ainsworth, P., Plunkett, A., Tucker, G. and Marson, H. (2006). The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. *Journal of Food Engineering*, **73**(2): 142–148.
- Diosady, L. L., Patton, D., Rosen, N. and Rubin, L. J. (1985). Degradation of wheat starch in a single screw extruder: mechano-kinetic breakdown of cooked starch. *Journal of Food Science*, **50**: 1697–1706.
- Diplock, A. T., Agget, P. J., Ashwell, M., Bornet, F., Fern, E. B., and Roberfroid, M. B. (1999). Scientific concepts of functional foods in Europe: consensus document. *British Journal of Nutrition*, **81**: 127.
- Domagala, J., Wszolek, M., Tamime, A. Y. and Kupiec-Teahan, B. (2013). The effect of trans-glutaminase concentration on the texture, syneresis and micro-structure of set-type goat's milk yoghurt during the storage period. *Small Ruminant Research*, **112**(3): 154-161.
- Drury, Colonel Heber. (1873). *The useful plants of India with notices of their chief medicinal value in commerce, medicine and the arts*. Higginbotham and Co., Madras.
- Dttrich, R., Dragonas, C., Kannenkeril, D., Hoffmann, I., Mueller, A., Beckmann, M. W. and Pischetsrieder, M. (2009). A diet rich in Maillard reaction products protects LDL against copper induced oxidation ex vivo, a human intervention trial. *Food Research International*, **42**(9): 1315–1322.
- Durling, N. E., Catchpole, O. J., Grey, J. B., Webby, R. F., Mitchell, K. A., Foo, L. Y. and Perry, N. B. (2007). Extraction of phenolics and essential oil from dried sage (*Salvia officinalis*) using ethanol–water mixtures. *Food Chemistry*, **101**:1417–1424.
- Edem, D. O., Ekwere, E. S. and Eka, O. U. (1994). Chemical evaluation of the effects of cooking on the nutritive value of conophor seeds (*Tetracardipium conophorum*). *Tropical Science*, **42**: 219-224.
- Eichner, K. and Karel, M. (1972). Influence of water content and water activity on the sugar-amino browning reaction in model systems under various conditions. *Journal of Agricultural and Food Chemistry*, **20**(2): 218–223.

- Eliasson, A. C. and Gudmundsson, M. (1996). Starch: Physicochemical and functional properties, Chapter 10, In: Carbohydrates in Food, A. C. Eliasson, (ed.). Marcel Dekker Inc., pp. 431-503.
- Englberger, L., Aalbersberg, W., Ravi, P., Bonnin, M., Marks, G. C., Fitzgerald, M. H. and Elymore, J. (2003). Further analysis on Micronesia banana, taro, breadfruit and other foods for provitamin A carotenoids and minerals. *Journal of Food Composition and Analysis*, **16**: 216–236.
- Espírito-Santo, A. P., Pereg, P., Converti, A. and Oliviera, M. N. (2012). Influence of milk type and addition of passion fruit peel powder on fermentation kinetics, texture profile and bacterial viability in probiotic yoghurts. *LWT - Food Science and Technology*, **47**(2): 393–399.
- Everett, D. W. and McLeod, R. E. (2005). Interactions of polysaccharides stabilizers with casein aggregates in stirred skim-milk yoghurt. *International Dairy Journal*, **15**: 1175–1183.
- Faller, A. L. K. and Fialho, E. (2009). The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking. *Food Research International*, **42**(1): 210–215.
- Femenia, A., Selvendran, R. R., Ring, S. G. and Robertson, J. A. (1999). Effects of heat treatment and dehydration on properties of cauliflower fibre. *Journal of Agricultural Food Chemistry*, **47**: 728–732.
- Femenia, A., García-Pascual, P., Simala, S. and Rossello, C. (2003). Effects of heat treatment and dehydration on bioactive polysaccharide acemannan and cell wall polymers from *Aloe barbadensis* Miller. *Carbohydrate Polymers*, **51**: 397–405.
- Fizman, S. M. and Salvador, A. (1999). Effect of gelatin on the texture of yoghurt and acid heat induced milk gels. *Food Research Technology*, **208**: 100–105.
- Fizman, S. M. and Salvador, A. (1999). Effect of gelatin on the texture of yogurt and of acid-heat-induced milk gels. *Z. Lebensm. Unters. Forsch.* **208**: 100–105.
- Fizman, S. M., Lluch, M. A. and Salvador, A. (1999). Effect of addition of gelatin on microstructure of acidic milk gels and yogurt and on their rheological properties, *International Dairy Journal*, **9**: 895–901.
- Fochtman, F. W., Manno, J. E., Winek, C. L. and Cooper, J. E. (1969). Toxicity of the genus *Dieffenbachia*. *Toxicology and Applied Pharmacology*, **15**: 38–45.
- Fox, P. F. and Mc Sweeney, P. L. H. (1998). Physical properties of milk. In P. F. Fox and P. L. H. Mc Sweeney (Eds.), *Dairy chemistry and biochemistry*. Blackie Academic and Professional, London, pp. 437–462.
- Franceschi, V. R. (1989). Calcium oxalate formation is a rapid and reversible process in *Lemna minor* L. *Protoplasma*, **148**: 130–139.
- Franceschi, V. R. and Horner, H. T. (1980). Calcium oxalate crystals in plants. *The Botanical Review*, **46**: 361–427.

- Franceschi, V. R. and Nakata, P. A. (2005). Calcium oxalate in plants: formation and function. *Annual Review of Plant Biology*, **56**: 41–71.
- FUFOSE (1999). Scientific Concepts of Functional Foods in Europe Consensus Document. *British Journal of Nutrition*, **81**: S1-S27.
- Furtado, C. X. (1940). The Malayan keladis and other edible aroids. M.A.H.A. Magazine (Singapore Gardening Society, Kuala Lumpur), **10**: 11–17.
- Gavrielidou, M. A., Vallous, N. A., Karapantsios, T. D. and Raphaelides, S. N. (2002). Heat transport to a starch slurry gelatinizing between the drums of a double drum dryer *Journal of Food Engineering*, **54**(1): 45–58.
- George, M. and Pandalai, K. M. (1949). Investigations on plant antibiotics, Part IV. Further search for antibiotic substances in Indian medicinal Plants. *Indian Journal of Medical Research*, **37**: 169-181.
- Giri, A., Kanawjia, S. K. and Rajoria, A. (2014). Effect of phytosterols on textural and melting characteristics of cheese spread. *Food Chemistry*, **157**: 240–245.
- Gliszczyn´ska-S´wigło, A., Ciska, E., Pawlak-Leman´ska, K., Chmielewski, J., Borkowski, T. and Tyrakowska, B. (2006). Changes in the content of health-promoting compounds and antioxidant activity of broccoli after domestic processing. *Food Additives and Contaminants*, **23**: 1088–1098.
- Green, B. G. and Gelhard, B. (1989). Salt as an oral irritant, *Chemical Senses*, **14**(2): 259-271.
- Gujska, E and Khan, K. (1991). Functional properties of extrudates from high starch fractions of navy and pinto beans and corn meal blended with legume high protein fractions. *Journal of Food Science*, **56**(2): 431–435.
- Gujska, E. and Khan, K. (1990). Effect of temperature on properties of extrudates from high starch fractions of navy, pinto and garbanzo beans. *Journal of Food Science*, **55**: 466–469.
- Gupta, K. C. and Viswanathan, R. (1956). Antitubercular substances from plants. A preliminary study. *Antibiotics and Chemotherapy*, **6**: 194–195.
- Gupta, R. (1982). Recent advances in cultivation of isabgol (*Plantago ovate* Forsk.) in India. In: Cultivation and Utilization of Medicinal Plants, Atal, C. K. and Kapar, B. M., Eds., CRC Press, Glasgow, United Kingdom, pp. 406–417.
- Güven, M., Yasar, K., Karaca, O. B. and Hayaloglu, A. A. (2005). The effect of inulin as a fat replacer on the quality of set-type low-fat yogurt manufacture. *International Journal of Dairy Technology*, **58**: 180–184.
- Guzel, D. and Sayar, S. 2012. Effect of cooking methods on selected physicochemical and nutritional properties of barlotto bean, chickpea, faba bean, and white kidney bean. *Journal of Food Science and Technology*, **49**(1): 89–95.

- Guzel-Seydim, Z. B., Sezgin, E. and Seydim, A. C. (2005). Influences of exopolysaccharide producing cultures on the quality of plain set type yogurt. *FoodControl*, 16: 205–209.
- Hanelt, P. and Institute of Plant Genetics and Crop Plant Research (2001). Mansfeld's encyclopedia of agricultural and horticultural crops, vol 6. Springer-Verlag, Berlin, Heidelberg, New York, pp. 2317–2340
- Hanes, D. A., Weaver, C. M., and Wastney, M. E. (1999). Calcium and oxalic acid kinetics differ in rats. *The Journal of Nutrition*, 129: 165–169.
- Hanes, D. A., Weaver, C. M., Heaney, R. P. and Wastney, M. E. (1999). Absorption of calcium oxalate does not require dissociation in rats. *The Journal of Nutrition*, 129:170–173.
- Hang, D. T. and Preston, T. R. (2010). Effect of processing Taro leaves on oxalate concentrations and using the ensiled leaves as a protein source in pig diets in central Vietnam. *Livestock Research for Rural Development*, 22(4): 110-119.
- Harwalkar, V. R. and Kalab, M. (1986). Relationship between micro-structure and susceptibility to syneresis in yoghurt made from reconstituted non-fat dry milk. *Food Microstructure*, 5: 287.
- Hashim, I. B., Khalil, A. B. and Afifi, H. S. (2009). Quality characteristics and consumer acceptance of yogurt fortified with date fiber. *Journal of Dairy Science*, 92: 5403–5407.
- Hatch, M. and Freel, R. W. (2005). Intestinal transport of an obdurate anion: oxalate. *Urological Research*, 33(1): 1-16.
- Hodgkinson, A. (1977). Oxalic acid in biology and medicine. Academic Press, London.
- Holloway, W. D., Argall, M. E., Jealous, W. T., Lee, J. A. and Bradbury, J. H. (1989). Organic acids and calcium oxalic acid in tropical root crops. *Journal of Agricultural and Food chemistry*, 37: 337-341.
- Hollyer, J.R. et al. (47 contributors). (1997). Taro Mauka to Makai: A Taro Production and Business Guide for Hawaii growers. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu.
- Holmes, P. R., Goodman, H. O. and Assimos, D. G. (1995). Dietary oxalate and its intestinal absorption. *Scanning Microscopy*, 9: 1109–1120.
- Hoover, R. and Manuel, H. (1996). The effect of heat–moisture treatment on the structure and physicochemical properties of normal maize, waxy maize, dull waxy maize and amylo-maize V starches. *Journal of Cereal Science*, 23: 153–162.
- Hoover, R. and Vasanthan, T. (1994). Effect of heat-moisture treatment on the structure and physic-chemical properties of cereal, legume, and tuber starches. *Carbohydrate Research*, 252: 33–53.

- Hsu, C. L., Chen, W. L., Weng, Y. M. and Tseng, C. Y. (2003). Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods. *Food Chemistry*, **83**: 85–92.
- Huang, A. S. and Hollyer, J. (1995) Manufacturing of acidity free raw flour from Araceae tubers. US Patent Numer- 5464646 dated Nov 7, 1995.
- Huang, A. S., Lam, S. Y., Nakayama, T. M. and Hui Lin. (1994). Microbiological chemical changes in poi stored at 20°C. *Journal of Agricultural and Food Chemistry*, **42**: 45-48.
- Hudgins, J. W., Krekling, T. and Franceschi, V. R. (2003). Distribution of calcium oxalate crystals in the conifers: a constitutive defense mechanism? *New Phytologist*, **159**: 677-690.
- Hussain, S. A. (2008). Studies on shelf life extension of cereal based fermented milk beverage. M Tech Thesis, Dairy Technology Division, National Dairy Research Institute, Karnal, India.
- Hussain, S. A. (2013). Development of technology for the manufacture of aloe vera supplemented probiotic *lassi*. PhD Thesis, Dairy Technology Division, National Dairy Research Institute, Karnal, India.
- Ilo, S., Tomschik, U., Berghofer, E. and Mundigler, N. (1996). The effect of extrusion operating conditions on the apparent viscosity and the properties of extrudates in twin-screw extrusion cooking of maize grits. *Lebensm-Wiss u-Technolo*, **29**: 593–598.
- Ingenpass, P. (1980). Food, flavouring, packaging and processing. *Journal of Food Science*, **16**: 345-400.
- Irvine, F. R. (1969). Cocoyam. In *West African Crops*. Oxford University Press, Oxford, UK, pp. 174-179.
- ISI (1981). *ISI Handbook of Food Analysis. Part-XI Dairy Products*. Indian Standards Institution, New Delhi.
- Isleten, M. and Karagul-Yuceer, Y. (2006). Effects of dried dairy ingredients on physical and sensory properties of non-fat yogurt. *Journal of Dairy Science*, **89**: 2865–2872.
- Ismail, A. and Lee, W. Y. (2004). Influence of cooking practice on antioxidant properties and phenolic content of selected vegetables. *Asia Pacific Journal of Clinical Nutrition*, **13** (Suppl.): S162.
- Iwuoha, C. I. and Kalu, F. A. (1995). Calcium oxalate and physico-chemical properties of cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) tuber flours as affected by processing. *Food Chemistry*, **54**: 61-66.
- Iyer, V., Salunkhe, D. K., Sathe, S. K., and Rockland, L. B. (1980). Quick-cooking beans (*Phaseolus vulgaris* L.): I. Investigations on quality. *Plant Foods for Human Nutrition*, **30**(1): 27-43.
- Jackson, M. G. (1977). Review article: The alkali treatment of straws, *Animal Feed Science and Technology*, **2**(2): 105-130.

- Jain, S., Dixit, V. K., Malviya, N. and Ambawatia, V. (2009). Antioxidant and hepatoprotective activity of ethanolic and aqueous extracts of *Amorphophallus campanulatus*. *Acta Pol Pharm*, **66**(4): 423-428
- Jamradloedluk, J., Nathakaranakule, A., Saponronnarit, S. and Prachayawarakorn, S. (2007). Influences of drying medium and temperature on drying kinetics and quality attributes of durian chip. *Journal of Food Engineering*, **78**: 198–205.
- Jaworska, D., Waszkiewicz-Robak, B., Kolanowski, W. and Swiderski, F. (2005). Relative importance of textural properties in the sensory quality and acceptance of natural yoghurts. *International Journal of Dairy Technology*, **58**:39–46.
- Jayaweera, D. M. A. (1981). Medicinal Plants used in Ceylon Part 1. National Science Council of Sri Lanka. Colombo.
- Jiang, Y. and Jiarui, F. D. (1998). Inhibition of polyphenol oxidase and the browning control of litchi fruit by glutathione and citric acid. *Food Chemistry*, **62**(1): 49-52.
- Jiang, Y. M., Fu, J. R., Zauberman, G. and Fuchs, Y. (1999). Purification of polyphenol oxidase and the browning control of litchi fruit by glutathione and citric acid. *Journal of the Science of Food and Agriculture*, **79**: 950–954.
- Jiang, Y., Pen, L. and Li, J. (2004). Use of citric acid for shelf life and quality maintenance of fresh-cut Chinese water chestnut. *Journal of Food Engineering*, **63**: 325–328
- Jimoh K. O. and Kolapo A. L. (2007). Effect of different stabilizers on acceptability and shelf stability of soy-yoghurt. *African Journal of Biotechnology*, **6**(8): 1000-1003.
- Jogdand, S. B., Lembhe, A. F., Ambadkar, R. K. and Chopade, S. S. (1991). Incorporation of additives to improve the quality of *dahi*. *Indian Journal of Dairy Science*, **44**(7): 459-460.
- Johns, T. and Kubo, I. (1988). A survey of traditional methods employed for detoxification of foods. *Journal of Ethnobiology*, **8**(1): 81-129.
- Joshi, S. G. (2000). Medicinal plants. Oxford and IBH Publishing, Calcutta. pp. 33.
- Judprasong, K., Charoenkiatkul, S., Sungpuag, P., Vasanachitt, K. and Nakjamanong, Y. (2006). Total and soluble oxalate contents in Thai vegetables, cereal grains and legume seeds and their changes after cooking. *Journal of Food Composition and Analysis*, **19**(4): 340–347.
- Kadam, S. S., Subramanyam, P., Jawale, J. K., Satwadhar, P. N. and Jadhav, S. J. (1981). Improvement in cooking quality of horse gram (*Dolichos biflorus*) by pre-soaking treatment with salt solution. *Plant Foods for Human Nutrition*, **31**(2): 171-174.
- Kadan, R. S., Bryant, R. J. and Pepperman, A. B. (2003). Functional properties of extruded rice flours. *Journal of Food Science*, **68**(5): 1669-1672.

- Kahkonen, M. P., Hopia, A. I. and Vuorela, H. J. (1999). Antioxidant activity of plant extracts containing phenolic compounds. *Journal of Agricultural and Food Chemistry*, **47**: 3954-3962.
- Kalita, D and Bora, R. L. (2008). Some folk medicines from Lakhimpur district, Assam. *Indian Journal of Traditional Knowledge*, **7**(3): 414-416.
- Kanning, M. W., Velde, F., Alting, A. C., Mulleners, L., Sein, A., Bleumink, B. and Buwalda, P. (2012). Improved creaminess in stirred yoghurt through amylo-maltase treated starch domain. *International Dairy Journal*, **27**(1/2): 86–91.
- Karanja, C., Njeri-Maina, G., Gabrejas, M., Esteban, R. S., Grant, G., Pusztai, A., Georget, D. M. R., Parker, M. L., Smith, A. C. and Waldron, K. W. (1996). Extrusion-induced modifications to physical and antinutritional properties of hard to cook beans. In IFR (Ed.), *Agri-food quality: An interdisciplinary approach*. Proceedings, RSC Food Chemistry group and the RSC Agriculture group, Norwich, 25–29 June, UK, pp. 279–287.
- Kaushal, P., Kumar, V. and Sharma, H. K. (2012). Comparative study of physico-chemical, functional, anti-nutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*) flour, pigeonpea (*Cajanus cajan*) flour and their blends. *LWT - Food Science and Technology*, **48**(1): 59–68.
- Kay, D. E. and Gooding, E. G. B. (1987). *Root crops ed.2, Crop and Product Digest No.2*, Tropical Development and Research Institute, London, **15**. pp.380.
- Kelsay, J. L. (1985). Effect of oxalic acid on calcium bioavailability. In: Kies, C. (ed.). *Nutritional bioavailability of calcium*. American Chemical Society, Washington, D.C., pp.105–116.
- Keogh, M. K. and O’Kennedy, B. T. (1998). Rheology of stirred yoghurt as affected by added milk fat, protein and hydrocolloids. *Journal of Food Science*, **63**(1): 108-112.
- Khan, A., Rahman, M. and Islam, M. S. (2008). Antibacterial, antifungal and cytotoxic activities of amblyone isolated from *Amorphophallus campanulatus*. *Indian Journal of Pharmacology*, **40**(1): 41-44
- Khan, A., Rahman, M. and Islam, M. S. (2009). Antibacterial, antifungal and cytotoxic activities of salviasperanol isolated from *Amorphophallus campanulatus*. *Pharmaceutical Biology*, **47**(12): 1187-1191.
- Khanal, R. C., Howard, L. R. and Prior, R. L. (2010). Effect of heating on the stability of grape and blueberry pomace procyanidins and total anthocyanins. *Food Research International*, **43**: 1464–1469.
- Khurana, H. K. and Kanawjia, S. K. (2007). Recent trends in development of fermented milk. *Current Nutrition & Food Science*, **3**: 91-108
- Kim, J. and Lee, Y. (2008). Effect of reaction pH on enolization and racemization reactions of glucose and fructose on heating with amino acid enantiomers and formation of melanoidins as result of the Maillard reaction. *Food Chemistry*, **108**(2): 582–592.

- Kim, N. Y., Joon, S. J. and Jang, S. M. (1993). Effect of blanching on the chemical properties of different kinds of spinach. *Journal of Korean Society of Food Science*, **9**: 204-209.
- Kinsella, J. E. (1976). Functional properties of proteins in foods: a survey. *Critical Reviews in Food Science and Nutrition*, **7**: 219–232.
- Kinsella, J. E., Damodaran, S. and German, B. (1985). Physicochemical and functional properties of oil seed proteins with emphasis on soy proteins. *New Protein Foods*, **5**: 107–179.
- Kirby, A. R., Ollett, A. L., Parker, R. and Smith, A. C. (1988). An experimental study of screw configuration effects in the twin screw extrusion cooking of maize flour grots. *Journal of Food Engineering*, **8**: 247–272.
- Kirthikar K. R. and Basu, B. D. (1987). Indian medicinal plants, vol IV. International Book Distributors, Dehradun.
- Kite, G. C. and Hetterschield, W. L. A. (1997). Inflorescence odours of *Amorphophallus* and *Pseudodracontium* (Araceae). *Phytochemistry*, **46**(1): 71-75.
- Kite, G. C., Sharp, H. J., Hill, P. S. and Boyce, P. C. (1997). Polyhydroxyalkaloids in the aroid tribes nephthytideae and aglaonemateae: phytochemical support for an intertribal relationship. *Biochemical Systematics and Ecology*, **25**(8): 757-766.
- Koç, B. and Eren, I. (2008). Modelling bulk density, porosity and shrinkage of quince during drying: The effect of drying method. *Journal of Food Engineering*, **85**(3): 340-349.
- Koca, N., Burdurlu, H. S. and Karadeniz, F. (2007). Kinetics of colour changes in dehydrated carrots. *Journal of Food Engineering*, **78**: 449–455.
- Kostoglou, M. and Karapantsios, T. D. (2003). On the thermal inertia of the wall of a drum dryer under a cyclic steady state operation. *Journal of Food Engineering*, **60**: 453–462
- Kulp, K. and Lorenz, K. (1981). Heat-Moisture Treatment of Starches. I. Physico-chemical Properties. *Cereal Chemistry*, **58**: 46–48.
- Kumar, S., Nath, V. and Das, B. (2004). Priorities of Horticulture Development in Jharkhand. In Sarkar, A.K. ed., *Sustainable development of horticultural crops*, Proceedings of State level Workshop held from September, 27-October, 1, 2004. SAMETI, Ranchi, Jharkand.
- Kyi, T. M., Daud, W. R. W., Mohammad, A. B., Samsudin, M. W., Kadhum, A. A. H. and Talib, M. Z. M. The kinetics of polyphenol degradation during the drying of Malaysian cocoa beans. *International Journal of Food Science and Technology*, **40**: 323–331.
- Laboratory Manual (1959). Methods of analysis of milk and its products. 3rd edn, Milk Industry Foundation, USA, pp: 283.
- Laderman, C. (1983). Wives and midwives childbirth and nutrition in rural Malaysia. University of California Press, California, p 247.

- Langdon, T. T. (1987). Preventing of browning in fresh pre- pared potatoes without the use of sulfiting agents. *Food Technology*, **41**: 64-67.
- Lawal, O. S. (2005). Studies on the hydrothermal modifications of new cocoyam (*Xanthosoma sagittifolium*) starch. *International Journal of Biological Macromolecules*, **37**: 268–277.
- Lazou, A. and Krokida, M. (2010). Functional properties of corn and corn–lentil extrudates. *Food Research International*, **43**(2): 609-616.
- Lebot, V. (2009). Tropical root and tuber crops: cassava, sweet potato, yams and aroids. In: Atherton, J. and Rees, A. (Eds.). *Crop Production Science in Horticulture Series*. CABI, Oxford.
- Ledward, D. A. (1993). Creating textures from mixed biopolymer systems. *Trends in Food Science and Technology*, **4**: 402–405.
- Lee, W. J. and Lucey, J. A. (2004). Structure and physical properties of yoghurt gels: Effect of inoculation rate and incubation temperature. *Journal of Dairy Science*, **87**: 3153–3164
- Lee, W. J. and Lucey, J. A. (2010). Formation and Physical Properties of Yogurt. *Asian-Australian Journal of Animal Sciences*, **23**(9): 1127-1136.
- Leonid, A. B., Vladimir, P.G., Andrew, V. B., Alexander, M. L., Valeriy, L. and Vladimir, A. K. (2006). The investigation of low temperature vacuum drying processes of agricultural materials. *Journal of Food Engineering*, **74**: 410–415.
- Lewicki, P. P. (1998). Effect of pre-drying treatment, drying and rehydration on plant tissue properties: A review. *International Journal of Food Properties*, **1**(1):1-22
- Lewicki, P. P. (2006). Design of hot air drying for better foods. *Trends in Food Science and Technology*. **17**: 153–163.
- Lewu, M. N., Adebola, P. O. and Afolayan, A. J. (2009). Effect of cooking on the mineral and antinutrient contents of the leaves of seven accessions of *Colocasia esculenta* (L.) Schott growing in South Africa. *Journal of Food, Agriculture and Environment*, **7**(3-4): 359-363.
- Li, B. B., Smith, B. and Hossain, M. M. (2006). Extraction of phenolics from citrus peels. I. Solvent extraction method. *Separation and Purification Technology*, **48**: 182-188.
- Liadakis, G. N., Floridis, A., Tzia, C. and Oreopoulou, V. (1993). Protein isolates with reduced gossypol content from screw-pressed cottonseed meal. *Journal of Agricultural and Food Chemistry*, **41**(6): 918–922.
- Liu, Q. (2005). Understanding starches and their role in food. S. Cui (Ed.), *Food Carbohydrates: Chemistry, Physical Properties and Applications*, CRC Press Taylor and Francis Group, New York, USA, pp. 309–355.
- Lobato-Calleros, C., Ramírez-Santiago, C., Vernon-Carter, E. J. and Alvarez-Ramirez, J. (2014). Impact of native and chemically modified starches

- addition as fat replacers in the visco-elasticity of reduced-fat stirred yogurt. *Journal of Food Engineering*, **131**: 110–115.
- Loh, J. and Breene, W. M. (1982). Between-species differences in fracturability loss: Comparison of the thermal behaviour of pectin and cell wall substances in potato and Chinese water chestnut. *Journal of Texture Studies*, **13**: 381–396.
- Lopez, J., Uribe, E., Vega-Galvez, A., Miranda, M., Vergara, J., Gonzalez, E. and Scala, K. D. (2010). Effect of air temperature on drying kinetics, vitamin C, anti-oxidant activity, total phenolic content, non-enzymatic browning and firmness of blueberries variety O'Neil. *Food and Bioprocess Technology*, **3**(5): 772-777.
- Lou, S., Lin, Y., Hsu, Y., Chiu, E. and Ho, C. (2014). Soluble and insoluble phenolic compounds and antioxidant activity of immature calamondin affected by solvents and heat treatment. *Food Chemistry*, **161**: 246-253.
- Lucey, J. A. (2002). Foundation scholar award formation and physical properties of milk protein gels. *Journal of Dairy Science*, **85**: 281-294.
- Lucey, J. A. (2004). Cultured dairy products: an overview of their gelation and texture properties. *International Journal of Dairy Technology*, **57**(2/3): 77–84.
- Luo, Z. and Gao, Q. (2011). Effect of enzyme-modified carboxymethyl starch as a fat replacer on the functional properties of sausages. *Starch–Stärke*, **63**(10): 661–667.
- Luthria, D. L. and Mukhopadhyay, S. (2006). Influence of sample preparation on assay of phenolic acids from eggplant. *Journal of Agriculture and Food Chemistry*, **54**: 41–47.
- Makris, D. P. and Rossiter, J. T. (2001). Domestic processing of onion bulbs (*Allium cepa*) and asparagus spears (*Asparagus officinalis*): effect on flavonol content and antioxidant status. *Journal of Agricultural and Food Chemistry*, **49**: 3216–3222.
- Malumba, P., Janas, S., Roiseux, O., Sinnaeve, G., Masimango, T.,Sindic, M., Deroanne, C. and Béra, F. (2010). Comparative study of the effect of drying temperatures and heat-moisture treatment on the physic-chemical and functional properties of corn starch. *Carbohydrate Polymers*, **79**(3): 633–641.
- Marshall, V. M. and Rawson, H. L. (1999). Effects of exo-polysaccharides producing strains of thermophilic lactic acid bacteria on the texture of stirred yoghurt. *International Journal of Food Science and Technology*, **34**: 137–143.
- Martin, F. L., Parker, A., Hort, J., Hollowood, T. A. and Taylor, A. J. (2005). Using vane geometry for measuring the texture of stirred yoghurt. *Journal of Texture Studies*, **36**: 421–438.
- Martín-Cabrejas, M. A., Aguilera, Y., Pedrosa, M., Cuadrado, C., Hernández, T., Díaz, S. and Esteban, R. M. (2009). The impact of dehydration process on

- anti-nutrients and protein digestibility of some legume flours. *Food Chemistry*, **114**: 1063–1068
- Martínez-Heras, R., Heredia, A., Castelló, M. L. and Andrés, A. (2014). Influence of drying method and extraction variables on the antioxidant properties of persimmon leaves. *Food Bioscience*, **6**: 1–8.
- Mathur, B. N. (1991). Indigenous milk products of India. The related research and technological requirements. *Indian Dairyman*. **42**:61
- Maurya, N. K. (2012). Development of technology of curcumin fortified lassi with enhanced functional attributes. MTech Thesis. Dairy Technology Division, National Dairy Research Institute, Karnal, India.
- May, R. J. (1984). *Kaikai Aniani: A Guide to Bush Foods, Markets and Culinary Arts of Papua New Guinea*. Robert Brown and Associates, Bathurst, Australia.
- McCord, J. D. and Kilara, A. (1983). Control of enzymatic browning in processed mushrooms (*Agaricus bisporus*). *Journal of Food Science*, **488**(5): 1479–1484.
- Medoua, N. G., Mbome Lape, I., Agbor-Egbe, T. and Mbofung, C. M. F. (2007) Antinutritional factors changes occurring in trifoliolate yam (*Dioscorea dumetorum*) tubers after harvest. *Food Chemistry*, **102**: 716–720.
- Mehmood, S. T, Masud, T., Mahmood, T.Y. and Maqsud, S. (2008). Effect of different additives from local source on the quality of yoghurt. *Pakistan Journal of Nutrition*, **7**(5): 695-699.
- Meyer, D., Bayarri, S., Tarrega, A. and Costell, E. (2011). Inulin as texture modifier in dairy products. *Food Hydrocolloids*, **25**: 1881-1890.
- Miranda, M., Maureira, H., Rodríguez, K. and Vega-Gálvez, A. (2009). Influence of temperature on the drying kinetics, physicochemical properties, and antioxidant capacity of *Aloe Vera* (*Aloe Barbadensis* Miller) gel. *Journal of Food Engineering*, **91**(2): 297–304.
- Modler, H. W. and Kalab, M. (1983). Microstructure of yogurt stabilized with milk proteins. *Journal of Dairy Science*, **66**: 430.
- Mohapatra, S., Panda, S. H., Sahoo, S. K., Sivakumar, P. S. and Ray, R. C. (2007). β carotene rich sweet potato curd: production, nutritional and proximate composition. *International Journal of Food Science and Technology*, **42**: 1305-1314.
- Moy, J. H., Shadbolt, B., Stoewsand, G. S. and Nakayama, T. O. M. (1979). The acidity factor in taro processing. *Journal of Food Processing and Preservation*, **3**: 139-144.
- Munea, M. A. M., Minka, S. R. and Mbomec, I. L. (2014). Optimising functional properties during preparation of cowpea protein concentrate. *Food Chemistry*, **154**:32–37

- Murakami, M., Yamaguchi, T., Takamura, H. and Matoba, T. (2004). Effects of thermal treatment on radical-scavenging activity of single and mixed polyphenolic compounds. *Journal of Food Science*, **69**: FCT7–FCT10.
- Murthy, G. N, Bhagavan, B. V. K., Ramanandam, G., Babu Ratan, P., Madhava Rao, D., Reddy, R. V. S. K. and Suryanarayana Reddy, P. (2008). *Amorphophallus* (var. *Gajendra*) in Andhra Pradesh. In Palaniswami, M.S. *et al.*, ed., National Seminar on *Amorphophallus*: innovative technologies, July 19-20, 2008, Patna, Bihar-abstract book, status papers and extended summary. pp.51-54
- Naczek, M. and Shahidi, F. (2006). Phenolics in cereals, fruits and vegetables: Occurrence, extraction and analysis. *Journal of Pharmaceutical and Biomedical Analysis*, **41**: 1523–1542.
- Nadkarni, K. M. and Nadkarni, A. K. (1999). Indian Materia Medica - with Ayurvedic, Unani-Tibbi, Siddha, Allopathic, Homeopathic, Naturopathic and Home remedies. Vol.1. Popular Prakashan Private Ltd., Bombay, India.
- Narayan, K. and Rao, M. S. N. (1982). Functional properties of raw and heat processed winged bean (*Psophocarpus tetragonolobus*) flour. *Journal of Food Science*, **47**(5): 1534–1538.
- Nataraj, H. N., Murthy, R. L. N. and Setty, S. R. (2009). In vitro quantification of flavonoids and phenolic content of – *suran*. *International Journal of Chemtech Research*, **1**(4): 1063-1067.
- Natraj, H. N., Murthy, R. L. N. and Setty, S. R. (2009). In vitro screening of antimicrobial activity and preliminary phytochemical screening of – *suran*. *Pharmacologyonline*, **1**: 189-194.
- Nixon, R. W. (1987). Acridity in Araceae. Honours thesis, Australian National University, Canberra, Australia.
- Njintang, N. Y., Mbofung, C. M. F. and Waldron, K. W. (2001). In vitro protein digestibility and physicochemical properties of dry red bean flour (*Phaseolus vulgaris*) flour: Effect of processing and incorporation of soybean and cowpea flour. *Journal of Agricultural and Food Chemistry*, **49**: 2465–2471.
- Njintang, Y. N. and Mbofung, C. M. F. (2003). Development of taro (*Colocasia esculenta* L. Schott) flour as an ingredient in food processing: effect of gelatinisation and drying temperature on the dehydration kinetics and colour of flour. *Journal of Food Engineering*, **58**: 259–265.
- Njintang, Y. N. and Mbofung, C. M. F. (2006). Effect of precooking time and drying temperature on the physico-chemical characteristics and in-vitro carbohydrate digestibility of taro flour. *Lebensmittel-Wissenschaft und Technologie*, **39**: 684–691.
- Noonan, S. C. and Savage, G. P. (1999). Oxalate content of foods and its effect on humans. *Asia Pacific Journal of Clinical Nutrition*, **8**: 64–74.
- Norton, T. R., Bristol, M. L., Read, G. W., Bushnell, O. A., Kashiwagi, M., Okinaga, C. M. and Oda, C. S. (1973). Pharmacological evaluation of

- medicinal plants from Western Samoa. *Journal of Pharmaceutical Sciences*, **62**: 1077.
- Ochse, J. J. and Van der Brink, R. C. B (1980). Vegetables of the Dutch East Indies. Amsterdam.
- Oh, H. E., Anema, S. G., Wong, M., Pinder, D. N. and Hemar, Y. (2007) Effect of potato starch addition on the acid gelation of milk. *International Dairy Journal*. **17**: 808-815.
- Okombo, J. A. and Liebman, M. (2010). Oxalate content of selected breads and crackers. *Journal of Food Composition and Analysis*, **23**: 118–121.
- Orikasa, T., Koide, S., Okamoto, S., Imaizumi, T., Muramatsu, Y., Takeda, J., Shiina, T. and Tagawa, A. (2014). Impacts of hot air and vacuum drying on the quality attributes of kiwifruit slices. *Journal of Food Engineering*, **125**: 51–58.
- Ortiz, J., Lemus-Modaca, R., Vega-Galvez, A., Ah-Hen, K., Puente-Daiz, L., Zura-Bravo, L. and Aubourg, S. (2013). Influence of air-drying temperature on drying kinetics, colour, firmness and biochemical characteristics of Atlantic salmon (*Salmo salar* L.) fillets. *Food Chemistry*, **139**(1-4): 162–169.
- Oseni, A. A. and Akindahunsi, A. A. (2011). Some Phytochemical Properties and Effect of Fermentation on the Seed of *Jatropha curcas* L. *American Journal of Food Technology*, **6**: 158-165.
- Osisiogu, I. U. W., Uzo, J. O. and Ugochukwu, E. N. (1974).The irritant effect of cocoyams. *Planta-Media*, **26**(2): 669.
- Paranjape, P. S., Karve, M. S. and Padhye, S. B. (2003). Characterization of tyrosinase and accompanying laccase from *Amorphophallus campanulatus*. *Indian Journal of Biochemistry & Biophysics*, **40**: 40-45.
- Park, S. S., Jang, M. S. and Lee, H. K. (1994). Effect of blanching condition on the chemical composition on the spinach grown in winter green house. *Journal of Korean Society of Food and Nutrition*, **23**: 62-67.
- Paseephol, T., Small, D. M. and Sherkat, F. (2008).Rheology and texture of set yogurt as affected by inulin addition. *Journal of Texture Studies*, **39**: 617-634.
- Passmore, R. and Eastwood, M. A. (1986).Human nutrition and Dietetics.8th ed. Churchill Livingstone, Edinburgh.
- Paull, R. E., Tang, C. S., Gross, K. and Uruu, G. (1999). The nature of the taro acidity factor. *Postharvest Biology and Technology*, **16**: 71–78.
- Perla, V., Holm, D. G. and Jayanty, S. S. (2012). Effects of cooking methods on polyphenols, pigments and antioxidant activity in potato tubers. *LWT - Food Science and Technology*, **45**(2): 161–171.
- Pilizota, V. and Subaric, D. (1998). Enzymatic browning of foods. *Food Technology and Biotechnology*, **36**(3): 219-227.

- Pizzocaro, F., Torreggiani, D. and Gilard, G. (1993). Inhibition of apple polyphenoloxidase (PPO) by ascorbic acid, citric acid and sodium chloride. *Journal of Food Processing and Preservation*, **17**: 21-30.
- Ponting, J. D. and Joslyn, M. A. (1948). Ascorbic acid oxidation and browning in apple tissue extract. *Archives in Biochemistry*, **19**: 47.
- Prabhu, M. J. (2008). Value addition leads to no tension agriculture. The Hindu Newspaper, dated 13.3.2008.
- Prajapathi, N. D., Purohit, S. S., Sharma, A. K. and Kumar, T. (2004). A hand book of medicinal plants—a complete source book. Jodhpur, India.
- Prathibha, S., Nambisan, B. and Leelamma, S. (1995). Enzyme inhibitors in tuber crops and their thermal stability. *Plant Foods for Human Nutrition*, **48**(3): 247-257.
- Prescott, J., Allen, S., and Stephens, L. (1984). Interactions between oral chemical irritation, taste and temperature. *Chemical Senses*, **18**(4): 389-404.
- Price, K. R., Casuscelli, F., Colquhoun, I. J. and Rhodes, J. C. (1998). Composition and content of flavonol glycosides in broccoli florets (*Brassica olearacea*) and their fate during cooking. *Journal of the Science of Food and Agriculture*, **77**: 468–472.
- Prychid, C. J. and Rudall, P. (1999). Calcium oxalate crystals in monocotyledons: a review of their structure and systematics. *Annals of Botany*, **84**: 725-729.
- Prychid, C. J., Jabaily, R. S. and Rudall P. J. (2008). Cellular ultrastructure and crystal development in *Amorphophallus* (Araceae). *Annals of Botany*, **101**: 983–995.
- Puncha-arnon, S. and Uttapap, D. (2013). Rice starch vs. rice flour: Differences in their properties when modified by heat–moisture treatment. *Carbohydrate Polymers*, **91**: 85–91.
- Purwal, L., Shrivastava, V. and Jain, U. K. (2011). Studies on anti-diarrhoeal activity of leaves of *Amorphophallus paeoniifolius* in experimental animals. *International Journal of Pharmaceutical Sciences and Research*, **2**: 468–471.
- Qu, W., Pan, Z. and Ma, H. (2010). Extraction modelling and activities of antioxidants from pomegranate marc. *Journal of Food Engineering*, **99**: 16–23.
- Quinteros, A., Farre, R. and Lagarda, M. J. (2003). Effect of cooking on oxalate content of pulses using an enzymatic procedure. *International Journal of Food Sciences and Nutrition*, **54**: 373–377.
- Quisumbing, E. (1978). Medicinal Plants of the Philippines. Katha Publishing Company. JMC PRESS, Quezon City, Philippines.
- Radi, M., Niakousari, M., and Amiri, S. (2009). Physico-chemical, textural and sensory properties of low fat yogurt produced by using modified wheat starch as fat replacer. *Journal of Applied Science*, **9**(11): 2194-2197.

- Ragaee, S., El-Sayed, M. and Abdel-Aal. (2006). Pasting properties of starch and protein in selected cereals and quality of their food products. *Food Chemistry*, **95**: 9–18
- Raju, P. N. and Pal, D. (2009). The physico-chemical, sensory, and textural properties of *misti dahi* prepared from reduced fat buffalo milk. *Food and Bioprocess Technology*, **2**:101–108.
- Raju, P. N. and Pal, D. (2014). Effect of dietary fibers on physico-chemical, sensory and textural properties of *misti dahi*. *Journal of Food Science and Technology*, **51**(11): 3124-3133.
- Ramakumar, P. (2011). The thickening effect of elephant foot yam in milk systems. MTech Thesis. Dairy Technology Division, National Dairy Research Institute, Karnal, India.
- Ramalingam, R., Bindu K. H., Madhavi, B. B., Nath, A. R. and Banji, D. (2010). Phytochemical and anthelmintic evaluation of corm of *Amorphophallus campanulatus*. *International Journal of Pharma and Biosciences*, **1**(2): 1-9.
- Ramanna, B. L. V. and Tiwari, B. D. (2000). Methods to enhance shelf stability of fermented milk products. *Indian Journal of Dairy Science*, **53**(2): 71-80.
- Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M. and Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, **26**: 1231–1237.
- Rehman, Z. U., Islam, M. and Shah, W. H. (2003). Effect of microwave and conventional cooking on insoluble dietary fibre components of vegetables. *Food Chemistry*, **80**: 237–240.
- Rehman, Z., Salariya, A. M. and Zafar, S. I. (2001). Effect of processing on available carbohydrate content and starch digestibility of kidney beans (*Phaseolus vulgaris* L.). *Food Chemistry*, **73**(3): 351–355.
- Remeuf, F., Mohammed, S., Sodini, I. and Tissier, J. P. (2003). Preliminary observations on the effects of milk fortification and heating on micro-structure and physical properties of stirred yogurt. *International Dairy Journal*, **13**(9): 773–782.
- Ren, Z., Pan, C., Jiang, L., Wua, C., Liu, Y., Zhong, Z., Ran, L., Ren, F., Chen, X., Wang, Y., Zhu, Y., and Huan, K. (2011). Oxalate-degrading capacities of lactic acid bacteria in canine feces. *Veterinary Microbiology*, **152**: 368–373
- Renard, C. M. G. C. (2005). Effects of conventional boiling on the polyphenols and cell walls of pears. *Journal of the Science of Food and Agriculture*, **85**: 310–318.
- Rodriguez, G., Vasseur, J. and Courtois, F. (1996). Design and control of drum dryers for the food industry. Part 1. Set-up of a moisture sensor and an inductive heater. *Journal of Food Engineering*, **28**: 271–282.
- Rouet-Mayer, M. A. and Philippon, J. (1986). Inhibition of catechol oxidases from apples by sodium chloride. *Phytochemistry*, **25**(12): 2717-2719.

- Roy, M. K., Takenaka, M., Isobe, S. and Tsushida, T. (2007). Antioxidant potential, anti-proliferative activities and phenolic content in water-soluble fractions of some commonly consumed vegetables: Effects of thermal treatment. *Food Chemistry*, **103**(1): 106–114.
- Rubis, D. D. (1990). Personal communique in regard to plantago and psyllium. *Indian Journal of Agronomy*, **21**: 509-510.
- Sabikhi, L. (2006). Developments in the manufacture of *lassi*. In *compendium of "Developments in traditional dairy products"*. Conducted by Centre for Advanced Studies in Dairy Technology from 10th-30th Dec, 2006 at NDRI, Karnal, India, pp: 64-67.
- Saha, B. P. and Hussain, M. (1983). A study of the irritating principles of aroids. *Indian Journal of Agriculture Science*, **53**: 833–836.
- Sahin, N. (2003). Oxalotrophic bacteria. *Research in Microbiology*, **154**: 399–407.
- Saikia, J. P. and Konwar, B. K. (2011) Biochemical composition and bioactivity of four edible aroids. Department of molecular biology and biotechnology, Tezpur University, Assam (Taken from <http://www.isrc.in/ojs/files/journals/5/articles/161-/submission/review/161-384-1-RV.doc>, 16 February, 2011).
- Saikia, T. and Borah, R. C. (1994). Biochemical composition of acrid and non-acrid *Amorphophallus* corms, *Journal of Agriculture Science Society of Northeast India*, **7**: 90–91.
- Sakai, W. S. (1979). Aroid root crops, acidity and raphides. In: *Tropical Foods, Chemistry and Nutrition* (Vol 1), ed Inglett, G. E. & Charalambous, G. Academic Press, NY, USA, pp. 265.
- Salvador, A. and Fiszman, S. M. (2004). Textural and sensory characteristics of whole and skimmed flavored set-type yogurt during long storage. *Journal of Dairy Science*, **87**: 4033-4041
- Sandoval-Castilla, O., Lobato-Calleros, C., Aguirre-Mandujano, E. and Vernon-Carter, E. J. (2004). Microstructure and texture of yogurt as influenced by fat replacers. *International Dairy Journal*, **14**(2):151–159.
- Sankaran, M. and Palaniswami, M. S. (2008). Biodiversity of *Amorphophallus* in India: Strategies for conservation and utilization. In: *National Seminar on Amorphophallus: Innovative Technologies. Abstract Book, Status Papers and Extended Summary* Palaniswami, M. S., Anil, S. R., Sajeev, M. S., Unnikrishnan, M., Singh, P. P. and Choudhary, B. C. (Eds.). 19-20 July 2008, Patna, Bihar, pp. 91
- Santerre, C. R., Cash, J. N. and Vannorman, D. J. (1988). Ascorbic acid/ citric acid combinations in the processing of frozen apple slices. *Journal of Food Science*, **53**: 1713-1716.
- Savage, G. P., Vanhanen, L., Mason, S. M. and Ross, A. B. (2000). Effect of cooking on the soluble and insoluble oxalate content of some New Zealand foods. *Journal of Food Composition and Analysis*, **13**: 201–206.
- Scalzo, R. L., Genna, A., Branca, F., Chedin, M. and Chassaingne, H. (2007). Anthocyanin composition of cauliflower (*Brassica oleracea* L. var. *botrytis*)

- and cabbage (*B. oleracea* L. var. *capitata*) and its stability in relation to thermal treatments. *Food Chemistry*, **107**(1): 136–144.
- Schellhaass, S. M. and Morris, H. A. (1985). Rheological and scanning electron microscopic examination of skim milk gels obtained by fermenting with ropy and non-ropy strains of lactic acid bacteria. *Food Microstructure*, **4**: 279.
- Sefa-Dedeh, S. and Agyir-Sackey, E. K. (2004) Chemical composition and the effect of processing on oxalate content of cocoyam *Xanthosoma sagittifolium* and *Colocasia esculenta* cormels. *Food Chemistry*, **85**: 479–487.
- Sendra, E., Kuri, V., Fernandez-Lopez, J., Sayas-Barbera, E., Navarro, C. and Perez-Alvarez, J. A. (2010). Viscoelastic properties of orange fiber enriched yogurt as a function of fiber dose, size and thermal treatment. *LWT—Food Science and Technology*, **43**(4): 708–714.
- Senel, E., Atamer, M., Gursoy, A. and Oztekin, F. S. (2011). Changes in some properties of strained (Süzme) goat's yoghurt during storage. *Small Ruminant Research*, **99**(2/3): 171-177.
- Sengupta, S., Chowdhary, B. M., Singh, B. N. and Ray R. N. (2008). Status of elephant foot yam cultivation in Jharkhand. In Palaniswami, M. S. *et al.* ed., *National Seminar on Amorphophallus: innovative technologies*, July 19-20, 2008, Patna, Bihar-abstract book, status papers and extended summary. pp. 30-34.
- Sharique, M. (2013). Texturization of Dahi for Extended Shelf Life. M Tech Thesis, Dairy Technology Division, National Dairy Research Institute, Karnal, India.
- Sharma, H. K., Chhangte, L. and Dolui, A. K. (2001). Traditional medicinal plants in Mizoram, India. *Fitoterapia*, **72**:146-161.
- Sharstry, R. A., Biradar, S. M., Mahadevan, K. M. and Habbu, P. V. (2010). Isolation and characterization of secondary metabolite from *Amorphophallus paeoniifolius* for hepatoprotective activity. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, **1**(4):429-437.
- Sheth, M. (2009).The goodness of curd.*NETNAA (Network for nutrition awareness and advocacy) food-for-health*. Series no.1.
- Shilpi, J. A., Ray, P. K., Sarder, M. M. and Uddin, S. J. (2005). Analgesic activity of *Amorphophallus campanulatus*. *Fitoterapia*, **76**(3): 367-369.
- Shoemaker, C. F., Nantz, J., Bonnans, S. and Noble, A. C. (1992). Rheological characterisation of dairy products. *Food Technology*, **25**: 98-104.
- Simpson, T. S., Savage, G. P., Sherlock, R. and Vanhanen, L. (2009). Oxalate content of silver beet leaves at different stages of maturation and the effect of cooking with different milk sources. *Journal of Agricultural and Food Chemistry*, **57**: 10804-10808.
- Singh, B., Sekhon, K. S. and Narpinder Singh. (2007). Effects of moisture, temperature and level of pea grits on extrusion behaviour and product characteristics of rice. *Food Chemistry*, **100**: 198–202.

- Singh, J., Gupta, C. R., Deo Shankar and Patel, D. (2008). Status of *Amorphophallus* in Chhattisgarh. In Palaniswami, M.S. et al. ed., *National Seminar on Amorphophallus: innovative technologies*, July 19-20, 2008, Patna, Bihar-abstract book, status papers and extended summary. pp. 51-54.
- Singh, P. P., Singh, C. P., Chaudhary, B. C. and Singh, J. R. P. (2008). Status of elephant foot yam cultivation in Bihar. In Palaniswami, M.S. et al. ed., *National Seminar on Amorphophallus: innovative technologies*, July 19-20, 2008, Patna, Bihar-abstract book, status papers and extended summary. pp. 19-24.
- Singh, R. (2007). Characteristics and technology of traditional cultured Indian milk products. *IDF Bulletin*. **415**:11-20.
- Singh, S. K., Rajasekar, N., Vinod-Raj, A. N. and Paramaguru, R. (2011). Hepatoprotective and antioxidant effects of *Amorphophallus campanulatus* against acetaminophen-induced hepatotoxicity in rats. *International Journal of Pharmacy and Pharmaceutical Sciences*, **3**: 202–205.
- Singleton, V. L., Orthofer, R. and Lamuela-Raventos, R. M. (1999). Analysis of total phenols and other oxidation substrates and oxidation substrates and antioxidants by means of Folin-Ciocalteu Reagent. In Abelson, J. N., Simon, M. and Sies, H. (eds), *Methods in Enzymology*. Vol. 299, Oxidants and antioxidants, Part A. Academic Press, Orlando, pp. 152-178.
- Sinha, P. R. and Sinha, R. N. (2000). Importance of good quality *dahi* in food. *Indian Dairyman*, **52**: 45-47.
- Siraj, V. V. and Balachandran, I. (1994). Ayurvedic drugs and their plant sources. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Skriver, A., Holstborg, J. and Qvist, K. B. (1999). Relation between sensory texture analysis and rheological properties of stirred yogurt. *Journal of Dairy Science*, **66**: 609–618.
- Sodini, I. F., Remeuf, S., Haddad, and Corrieu, G. (2004). The relative effect of milk base, starter, and process on yogurt texture: a review. *Critical Reviews in Food Science and Nutrition*, **44**(2): 113-137.
- Spillman, D. and Farr, S. (1983). Consumer acceptance of yoghurt containing vegetables. *Cultured Dairy Products Journal*, **11**: 10-13.
- Staffolo, M. D., Bertola, N., Martino, M. and Bevilacqua, A. (2004). Influence of dietary fiber addition on sensory and rheological properties of yogurt. *International Dairy Journal*, **14**: 263–268.
- Steventon, A. J., Parkinson, C. J., Fryer, P. J. and Bottomley, R. C. (1990). The rheology of yoghurt. In: *Rheology of Food, Pharmaceutical and Biological Materials with General Rheology*, Carter, R. E., Ed., Elsevier Applied Science, London, United Kingdom, pp. 196–210.
- Stone, H., Sidel, H., Oliver, S., Woodesey, A. and Singlehon, R. C. (1974). Sensory evaluation by quantitative descriptive analysis. *Food Technology*, **28**(1): 24-26.

- Sun, R., Lawther, J. M. and Banks, W. B. (1995). Influence of alkaline pre-treatments on the cell wall components of wheat straw, *Industrial Crops and Products*, **4**(2): 127-145.
- Sundaresan, S. (2005). Acridity of edible aroids. Technical bulletin series: 38. CTCRI. Thiruvananthapuram, Kerala, India.
- Sundaresan, S. and Nambisan, B. (2008). Acridity of *Amorphophallus* and the processing methods for its application. In Palaniswami, M.S. et al. ed., National Seminar on *Amorphophallus*: innovative technologies, July 19-20, 2008, Patna, Bihar-abstract book, status papers and extended summary. pp. 194-195
- Sunnell, L. A. and Healey, P. L. (1979). Distribution of calcium oxalate idioblasts in corms of taro (*Colocasia esculenta*). *American Journal of Botany*, 1029-1032.
- Suzuki, M. (1980). 3,4-Dihydroxybenzaldehyde-D-glucoside, the irritant substance of konnyaku. *Journal of Food Science*, **45**: 1075–1077.
- Tamime, A. Y. and Robinson, R. K. (1999). *Yoghurt Science and Technology*. Woodhead Publishing Limited, Cambridge, United Kingdom.
- Tang, J., Feng, H. and Shen, H. Q. (2003). Drum drying, in *Encyclopaedia of Agricultural and Food Engineering*, D. R. Heldman (ed.). Marcel Dekker, Inc., New York, pp. 211-214.
- Tasneem, M., Siddique, F., Ahmad, A., Farooq, U. (2014). Stabilizers: Indispensable substances in dairy products of high rheology. *Critical Reviews in Food Science and Nutrition*, **54**(7): 869-879.
- Taufel, K. and Voigt, T. (1964). Natrium chlorid als inhibitor bei der enzymatischen braunung von apfeln. *Nahrung*, **8**: 80.
- Teggatz, J. A. and Morris, H. A. (1990). Changes in the rheology and micro-structure of ropy yogurt during shearing. *Food Structure*, **9**: 133.
- Tiwari, B. D. (1997). 'Technology for *lassi*' in short course on Advances in Traditional Dairy products. 16 December, 1997- 6 January, 1998. Centre for Advanced Studies in Dairy Technology, National Dairy Research Institute, Karnal. pp. 103-106.
- Toma, R. B., Tabekhia, M. M. and Williams, J. D. (1979). Phytate and oxalate contents in sesame seed (*Sesamum indicum* L.) *Nutrition Reports International*, **20**: 25-31.
- Tortoe, C., Orchard, J. and Beezer, A. (2007). Prevention of enzymatic browning of apple cylinders using different solutions. *International Journal of Food Science and Technology*, **42**: 1475–1481.
- Traditional Medicine Database, (2002). National Department of Health, Govt. of Papua New Guinea, Waigani, N.C.D. Papua New Guinea.
- Tripathi, A. S., Chitra, V., Sheikh, N. W., Mohale, D. S. and Dewani, A. P. (2010). Immunomodulatory activity of the methanol extract of *Amorphophallus*

- campanulatus* (Araceae) tuber. *Tropical Journal of Pharmaceutical Research*, **9**(5): 451-454.
- Tu, J. C. C. (1981). Novel aroid products. US patent no. 4246289, Jan 20, 1981.
- Udosen, E. O. and Ukpanah, U. M. (1993). The toxicants and phosphorus content of some Nigerian vegetables. *Plants Foods for Human Nutrition*, **44**: 285–289.
- Upadhyay, B., Parveen., Dhaker, A. K. and Kumar, A. (2010). Ethnomedicinal and ethnopharmaco-stastical studies of Eastern Rajasthan, India. *Journal of Ethnopharmacology*, **129**: 64–86.
- Urga, K., Fufa, H., Biratau, E. and Gebretsadik, M. 2006. Effects of blanching and soaking on some physical characteristics of grass pea (*Lathyrus sativus*). *African Journal of Food Agriculture Nutrition and Development*, **6**(1):1-17.
- Urula, N. and Lähteenmäki, L. (2004). Attitudes behind consumers' willingness to use functional foods. *Food Quality and Preference*, **15**: 793–803
- Uzogara, S. G., Morton, I. D. and Daniel, J. W. (1990). Changes in some antinutrients of cowpeas (*Vigna unguiculata*) processed with kanwa alkaline salt. *Plant Foods for Human Nutrition*, **40**: 249-258.
- Uzogara, S. G., Morton, I. D. and Daniel, J. W. (1988). Quality changes and mineral content of cowpea (*Vigna unguiculata* L. Walp) seeds processed with 'Kanwa' alkaline salt. *Food Chemistry*, **30**(1): 1–18.
- Vallejo, F., Tomás-Barberán, F. and García-Viguera, C. (2003). Phenolic compound contents in edible parts of broccoli inflorescences after domestic cooking. *Journal of the Science of Food and Agriculture*, **83**: 1511–1516.
- Vallous, N.A, Gavrielidou, M. A., Karapantsios, T. D. and Kostoglou M. (2002). Performance of a double drum dryer for producing pre-gelatinized maize starches. *Journal of Food Engineering*, **51**: 171–183.
- Vamos-Vigyazo, L. (1981). Polyphenol oxidase and peroxidase in fruits and vegetables. *Critical Reviews in Food Science and Nutrition*, **15**: 49–127.
- Van-Vliet, T., Lucey, J. A., Grolle, K. and Walstra, P. (1997). Rearrangements in acid-induced casein gels during and after gel formation. In: *Food Colloids: Proteins, Lipids and Polysaccharides*, Dickinson E. and Bergenstahl, B., Eds., Royal Society of Chemistry, Cambridge, United Kingdom, pp. 335–345.
- Vega-Gálvez, A., Lemus-Mondacaa, R., Bilbao-Sainz, C., Fitoc, P. and Andre´s, A. (2008). Effect of air drying temperature on the quality of rehydrated dried red bell pepper (var. Lamuyo). *Journal of Food Engineering*, **85**: 42–50.
- Vega-Gálvez, A., Ah-Hen, K., Chacana, M., Vergara, J., Martínez-Monzó, J., García-Segovia, P. and Scala, K. D. (2012). Effect of temperature and air velocity on drying kinetics, antioxidant capacity, total phenolic content, colour, texture and microstructure of apple (var. Granny Smith) slices. *Food Chemistry*, **132**(1).

- Volk, G. M., Lynch-Holm, V. M., Kostman, T. A., Goss, L. J. and Franceschi, V. R. (2002). The role of druse and raphide calcium oxalate crystals in tissue calcium regulation in *Pistia stratiotes* leaves. *Plant Biology*, **4**: 34–45.
- Wachtel-Galor, S., Wong, K. W. and Benzie, I. F. F. (2008). The effect of cooking on *Brassica* vegetables. *Food Chemistry*, **110**(3): 706–710.
- Walter, W. G. and Khanna, P. N. (1972). Chemistry of the aroids. I. *Dieffenbachia*, *sequine*, *amoena* and *picta*. *Economic Botany*, **26**: 364–372.
- Wanasundera, J. P. D. and Ravindran, G. (1992). Effects of cooking on the nutrient and anti-nutrient content of yam tubers (*Dioscorea alata* and *Dioscorea esculenta*). *Food Chemistry*, **45**: 247-250.
- Wanasundera, J. P. D. and Ravindran, G. (1994). Nutritional assessment of yam (*Dioscorea alata*) tubers. *Plant Foods for Human Nutrition*, **46**: 33-39.
- Wang, W. Q., Bao, Y. H. and Chen, Y. (2013). Characteristics and antioxidant activity of water-soluble Maillard reaction products from interactions in a whey protein isolate and sugars system. *Food Chemistry*, **139**: 355–361.
- Wasnik, P. G., Nikam, P. B., Dhotre, A. V., Waseem, M., Khodwe, N. M. and Meshram, B. D. (2013). Physico-chemical and textural properties of Santra burfi as influenced by orange pulp content. *Journal of Food Science and Technology* (in press).
- Watcharatewinkul, Y., Puttanlek, C., Rungsardthong, V. and Uttapap, D. (2009). Pasting properties of a heat-moisture treated canna starch in relation to its structural characteristics. *Carbohydrate Polymers*, **75**(3): 505–511.
- Watt, G. (1889). Dictionary of economic plants of India, vol 2. Supt. Govt. Printing, Calcutta, India.
- Weenen, H., Van Gemert, L.J., Van Doorn, J. M., Dijksterhuis, G. B. and Wijk, R. A. D. E. Texture and mouth-feel of semi-solid foods: Commercial mayonnaises, dressings, custard desserts and warm sauces. *Journal of Texture Studies*, **34**: 159–17.
- Weese, J. S., Weese, H. E., Yuricek, L. and Rousseau, J. (2004). Oxalate degradation by intestinal lactic acid bacteria in dogs and cats. *Veterinary Microbiology*, **101**: 161–166.
- Whistler, R. L. and beMiller, J. N. (1958). Alkaline degradation of polysaccharides. *Advances in Carbohydrate Chemistry*, **13**: 289-329.
- WHO (2002). World Health Organization. Globalization, diets and non-communicable diseases, WHO Library Cataloguing-in-Publication Data, ISBN 9241590416
- Williams, R. P. W., Glagovskaia, O. and Augustin, M. A. (2004). Properties of stirred yogurts with added starch: effects of blends of skim milk powder and whey protein concentrate on yogurt texture. *Australian Journal of Dairy Technology*, **59**(3): 214-220.
- Xiao, B., Sun, X. F. and Sun R. C. (2001). Chemical, structural, and thermal characterizations of alkali-soluble lignins and hemicelluloses, and cellulose

- from maize stems, rye straw, and rice straw. *Polymer Degradation and Stability*, **74**(2): 307-319
- Xu, B. and Chang, S. K. C. (2008). Effect of soaking, boiling, and steaming on total phenolic content and antioxidant activities of cool season food legumes. *Food Chemistry*, **110**(1): 1–13.
- Xu, F., Zheng, Y., Yang, Z., Cao, S., Shao, X. and Wang, H. (2014). Domestic cooking methods affect the nutritional quality of red cabbage. *Food Chemistry*, **161**: 162-167
- Yadav, A. R., Guha, M., Tharanathan, R. N. and Ramteke, R. S. (2006). Changes in characteristics of sweet potato flour prepared by different drying techniques. *LWT – Food Science and Technology*, **39**(1): 20–26.
- Yang, B. Y. and Montgomery, R. (1996). Alkaline degradation of glucose: effect of initial concentration of reactants. *Carbohydrate Research*, **280**: 27-45.
- Yen, G. C. and Hsieh, P. (1995). Anti-oxidative activity and scavenging effects on active oxygen of xylose-lysine Maillard reaction products. *Journal of Science of Food and Agriculture*, **67**: 415–420.
- Yesodharan, K. and Sujana, K. A. (2007). Wild edible plants traditionally used by the tribes in the Parambikulam Wildlife Sanctuary, Kerala, India. *Natural Product Radiance*, **6**(1): 74-80.
- Zare, F., Boye, J. I., Orsat, V., Champagne, C. and Simpson, B. K. (2011). Microbial, physical and sensory properties of yogurt supplemented with lentil flour. *Food Research International*, **44**: 2482–2488.

Annexure

Composition of dry elephant foot yam powder

Constituent	Percent
Moisture	6.40 ± 0.03
Fat	0.22 ± 0.02
Protein	6.31 ± 0.12
Carbohydrates	82.95*
Ash	4.12 ± 0.05

*By difference; mean ± SE, n=3

Fibre content of psyllium husk preparation

Constituent	Percent
Moisture (by weight)	10.82
Fibre (dry basis)	94.80

(Adapted from Arora (2006))

Annexure-2

Sensory Score Card

1. Please rate the yam-milk mix for sensory attributes according to the 9-point hedonic scale. Kindly mix the sample thoroughly before judging.

<u>Hedonic Scale</u>	<u>Score</u>
Liked extremely	9
Liked very much	8
Liked moderately	7
Liked slightly	6
Neither liked nor disliked	5
Disliked slightly	4
Disliked moderately	3
Disliked very much	2
Disliked extremely	1

Desired attributes:
¹Colour and appearance: Whitish (like milk)
²**Flavour: Like milk (without any off flavour)**
³**Acridity: Itchy sensation felt in the mouth or throat. Absence of acridity is liked**
⁴Mouthfeel: Smooth
 (Attributes to be focused more in bold)

Characteristics	Sample No.			
	1	2	3	4
Colour and Appearance ¹				
Flavour²				
Acridity³				
Mouthfeel ⁴				

REMARKS:

Signature:

Sensory Score Card

Please evaluate the following sample(s) for the acidity.

Gently apply the the paste on the soft part of the forearm and feel the itchy sensation after 1-2 min. Kindly make a “vertical mark” with sample number along the scale to indicate the intensity of acidity.

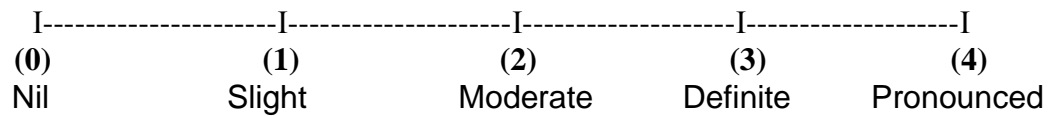
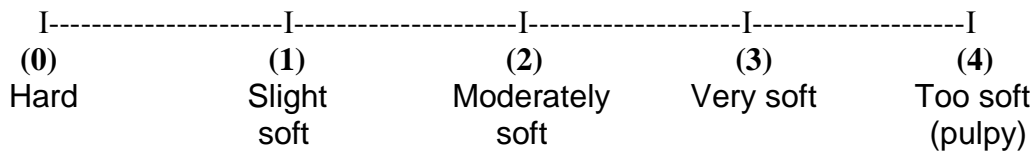
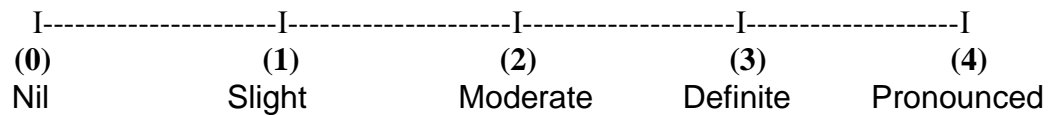
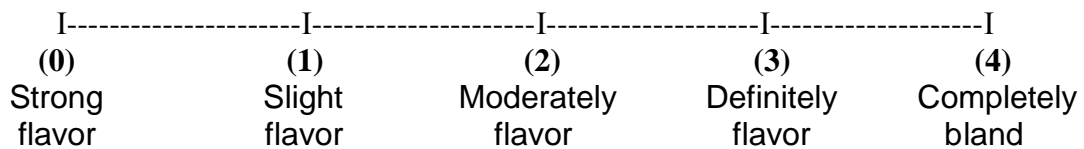
I-----I	I-----I	I-----I	I-----I	I-----I
(0)	(1)	(2)	(3)	(4)
Nil	Slight	Definite	Pronounced	Extreme

REMARKS:

Signature:

Sensory Score Card

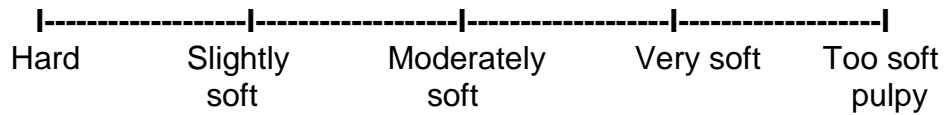
Kindly evaluate the given sample of elephant foot yam for given sensory attributes. Make a “vertical mark” with sample number along the scale, to indicate the intensity of attribute.

1. Darkness**2. Softness****3. Acridity****4. Blandness (of taste)**

Sensory Score Card

Please evaluate the given sample(s) for following attributes. Kindly make a “vertical mark” with sample number along the scale.

1. Softness:



2. Acridity:



3. Colour (Evaluate on the basis of 9 point hedonic scale)

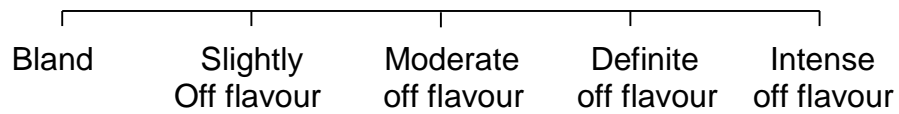
Sample No.	Rating	Sample No.	Rating	Sample No.	Rating

Signature

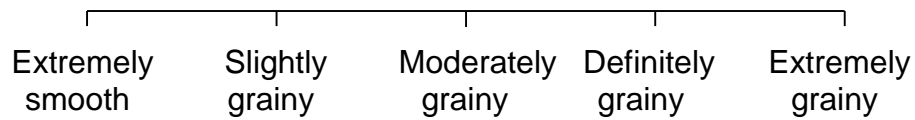
Sensory Score Card

Please evaluate the given samples for flavour (*degree of blandness*) and mouthfeel (*degree of smoothness*) using the respective linear scales given below. Kindly make a “vertical mark” along the scale and give sample number to indicate the attribute intensity.

1. Flavour



2. Mouthfeel



Signature

Sensory Score Card

Kindly evaluate the given sample(s) of *dahi* on 5 point scheme*:

Characteristic	Sample No				
	1	2	3	4	5
Appearance					
Firmness					
Consistency					
Flavour					
Mouthfeel					

Five point scheme *

Points	Description of property
5	Very good, Ideal
4	Good
3	Satisfactory, few mistakes
2	Not very satisfactory , distinct mistakes
1	Not satisfactory
0	Bad, tainted

Comments (if any): -----

Signature

Sensory Score Card

Please rate the given sample of *lassi* for sensory attributes according to the 9-point hedonic scale. Kindly mix the sample thoroughly before judging.

<u>Hedonic Scale</u>	<u>Score</u>
Liked extremely	9
Liked very much	8
Liked moderately	7
Liked slightly	6
Neither liked nor disliked	5
Disliked slightly	4
Disliked moderately	3
Disliked very much	2
Disliked extremely	1

Characteristics	Sample No.			
	1	2	3	4
Appearance				
Flavor				
Consistency				
Mouthfeel				
Overall acceptability				

REMARKS:

Signature:

Electrical energy required per day for operating various equipment

Equipment/Utility	No. of eqp.	Power (Kw)	Hour	Electrical energy/day (Kwh)
Milk pump	2	1.5	3.5	10.5
Plate heat exchanger	1	2.5	2	5
Plate chiller	1	1.5	4	6
Refrigerated storage tank	1	1	12	12
Multipurpose tank	1	1	9	9
Refrigeration (2.5 tonne)	2	8.75	9	157.5
Homogenizer	1	15	4	60
Steam boiler	1	1.5	6	9
Cont. Belt Drier	1	13.5	4	54
Total				323

Cost of major raw material required

Sr. No.	Items	Requirement (kg)		Rate (Rs/kg)	Annual cost (Rs)
		Daily	Annual		
1	Milk	2500	750000	30	22500000
2	Starter culture	5	1500	250	375000
3	Yam	900	270000	25	6750000
4	SMP	50	15000	150	2250000
5	Psyllium powder	0.25	75	125	37500
Total					31912500
5	PS cups	20000	6000,000	0.3	3000000
Total					33912500

Annexure-11

**Items of major capital investment along with their cost and annual depreciation
for preparing dahi**

Items	Particulars	No.	Rate (Rs)	Estimated cost (Rs)	Rate of depreciation (%)	Annual depreciation (Rs)
Building	1500 m ²	1	7200000	7200000	5	360000
Milk reception equipment (weighing balance, Plate chiller	5000 L/h	1	100000	100000	5	5000
Storage tank	1000 L/h	1	100000	100000	5	5000
Balance tank	1000 L	3	25000	75000	5	3750
Feed pump	250 L	2	10000	20000	5	1000
PHE	2 hp	2	50000	100000	10	10000
Multipurpose tank with agitator	1000 L/h	1	300000	300000	5	15000
Refrigeration unit	1000 L	3	50000	150000	5	7500
Steam boiler	2.5 tonne	2	150000	300000	15	45000
Homogenizer	500 kg/h	1	500000	500000	15	75000
Pipe and fittings accessories	1000 L	1	500000	500000	5	25000
Incubation chamber	6m ²	1	100000	100000	5	5000
storage tank	3000L	2	50000	100000	5	5000
Cont belt drier	16.2 KL/h	1	500000	500000	10	50000
Total				11045000		617250