

STUDIES ON NUTRITIONAL, STRUCTURAL, FUNCTIONAL AND STABILITY CHARACTERISTICS OF BAKERY PRODUCTS FORMULATED WITH SURIMI POWDER

*Thesis submitted in part fulfillment of the requirements of the Degree of
Doctor of Philosophy in Fish Processing Technology
to the Tamil Nadu Dr. J. Jayalalithaa Fisheries University,
Nagapattinam.*

A. BRITA NICY, M.F.Sc.

I.D.No. DPF (T) 16029 (FPT)



**DEPARTMENT OF FISH PROCESSING TECHNOLOGY
FISHERIES COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU Dr. J. JAYALALITHAA FISHERIES
UNIVERSITY THOOTHUKUDI-628008**

2019

CERTIFICATE

This is to certify that the thesis entitled, “**Studies on Nutritional, Structural, Functional and Stability Characteristics of Bakery Products Formulated with Surimi Powder,**” submitted in part fulfillment of the requirements for the degree of **Doctor of Philosophy in Fish Processing Technology** to the Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam, is a record of bonafide research work carried out by **Miss. A. BRITA NICY, DPF (T) 16029 (FPT)** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or similar titles or prizes and that part of thesis has been published in peer reviewed journal(s) and copy / copies appended.

Place : Thoothukudi

CHAIRMAN

Date :

APPROVED

Chairman : Dr. P. VELAYUTHAM

Members : 1. Dr. R. JEYA SHAKILA
: 2. Dr. N. NEETHISELVAN
: 3. Dr. S. BALASUNDARI

Place :

EXTERNAL EXAMINER

Date :

ACKNOWLEDGMENT

I express my sincere gratitude to my chairman, **Dr. P. Velayutham**, Dean i/c, Fisheries College and Research Institute, Thoothukudi for his guidance, encouragement and support to carry out this research successfully.

I have great pleasure in expressing my deep sense of gratitude to my advisory committee members, **Dr. R Jeya Shakila**, Professor and Head, Department of Fish Quality Assurance and Management, Fisheries College and Research Institute, Thoothukudi, **Dr. N. Neethiselvan**, Professor and Head, Centre for Fisheries Technology Training and Incubation Centre, Fisheries College and Research Institute, Thoothukudi and **Dr. S. Balasundari**, Professor and Head, Department of Fish Processing Technology, Dr. MGR. Fisheries College and Research Institute, Ponneri for their guidance throughout the period of study.

I owe my sincere gratitude to **Dr. S. Felix**, Vice-Chancellor, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam for providing me the facilities to carry out this research at Fisheries College and Research Institute, Thoothukudi.

I owe my heartfelt gratitude to **Dr. G. Sugumar** and **Dr. D. Sukumar** for their guidance and encouragement and also for providing the necessary facilities to carry out this study.

I express my deep sense of gratitude to **Mr. P. Ganesan** and **Mr. Vijayarahavan**, Assistant Professors, Department of Fish processing Technology whose guidance, encouragement and suggestions have contributed immensely in the completion of this research.

I am thankful to **Dr. N.V. Sujathkumar**, Professor, Department of Fisheries Extension, Economics and Statistics, Fisheries College and Research Institute, Thoothukudi for his guidance throughout this research.

I also thank **Mr. R. Kumaresan**, Librarian for his valuable help in the collection of reference material.

I would like to express special thanks to my dear friend **Mrs. Kanaga V**, Teaching Assistant, Department of Fisheries Extension, Economics and Statistics, Fisheries College and Research Institute, Thoothukudi for her frequent help and support.

I express my thanks for cooperation, assistance and encouragement provided by my dear friends, seniors and juniors, **Ms. Gopika R, Ms. Drishya Antony, Ms. JyotiSaroj, Mr. Neeraj Pathak, Ms. Priyanka Druv, Mrs. Harsha Haridas, Mrs. Chitra Soman, Ms. Lakshmi Haridas, Ms. Canciyal Johnson, Ms. Neetha Shenoy, Ms. K. Hema and Ms. Triveni K.**

It is worthy to mention the love, patience, enthusiasm, and everlasting support from my beloved **Parents**, who helped me a lot for the successful completion of the thesis.

(A. BRITA NICY)

ABSTRACT

Title : Studies on nutritional, structural, functional and stability characteristics of bakery products formulated with surimi powder.

Name of the student : Brita Nicy A

Degree : Ph.D.

Chairman : Dr. P. Velayutham

Department : Fish Processing Technology

College : Fisheries College and Research Institute, Thoothukudi

Year and University : 2019, Tamil Nadu Dr. J. Jayalalithaa Fisheries University

This research was aimed to evaluate the physico-chemical and nutritional qualities of bakery products such as biscuits, cake and bread produced from itoyori surimi in the form of freeze dried and oven dried powder, based on proximate composition, effects of surimi powder incorporation and storage stability. Freeze dried and oven dried surimi powder were used in production of bakery products by replacing 10%, 20% and 30% of maida in chocolate biscuit and chocolate cake and 5%, 10% and 15% of maida in bread to ensure the quality and acceptability of the bakery products. Based on the results obtained from sensory and nutritional evaluation of bakery products fortified with surimi powder, 10% surimi powder incorporated bakery products were organoleptically accepted and the nutritional quality of products significantly ($p < 0.05$) improved. The proximate composition of biscuits with freeze dried surimi (FDS) and oven dried surimi (ODS) powder were

estimated and the results showed that moisture, ash, fat, protein and carbohydrates contents in control biscuits and biscuit incorporated with 10% FDS powder and 10% ODS powder were $2.19 \pm 0.09\%$, $1.26 \pm 0.05\%$, $25.26 \pm 0.23\%$, $6.22 \pm 0.09\%$ and $65.07 \pm 0.27\%$, respectively, $2.38 \pm 0.06\%$, $1.73 \pm 0.06\%$, $24.83 \pm 0.04\%$, $9.21 \pm 0.11\%$ and $61.85 \pm 0.15\%$, respectively and $2.01 \pm 0.08\%$, $1.52 \pm 0.06\%$, $24.90 \pm 0.03\%$, $9.00 \pm 0.09\%$ and $62.56 \pm 0.08\%$, respectively. Mineral content and amino acid composition were also analysed. The scores for overall acceptability of control biscuit, biscuit incorporated with 10% FDS and biscuit incorporated with 10% ODS powder were 8.90 ± 0.31 , 8.83 ± 0.38 and 8.83 ± 0.38 , respectively. The proximate composition of bread incorporated with FDS powder and that incorporated with ODS powder were estimated and the results showed that the moisture, ash, fat, protein and carbohydrates content in control bread were $20.49 \pm 0.07\%$, $0.30 \pm 0.00\%$, $3.46 \pm 0.02\%$, $8.06 \pm 0.08\%$ and $67.69 \pm 0.07\%$, respectively, while in bread incorporated with 10% FDS powder were $20.45 \pm 0.19\%$, $0.73 \pm 0.06\%$, $3.62 \pm 0.03\%$, $13.36 \pm 0.04\%$ and $61.84 \pm 0.23\%$, respectively, and in bread incorporated with 10% ODS powder were $20.73 \pm 0.16\%$, $0.63 \pm 0.06\%$, $3.54 \pm 0.02\%$, $13.21 \pm 0.11\%$ and $61.89 \pm 0.28\%$, respectively. The scores for overall acceptability of bread incorporated with FDS powder on an average for control bread, bread incorporated with 10% FDS powder and 10% ODS powder were 8.77 ± 0.43 , 8.47 ± 0.51 and 8.03 ± 0.61 , respectively. The proximate composition of cake with FDS and ODS powder were estimated and the moisture, ash, fat, protein and carbohydrates contents in control cake and cake incorporated with 10% FDS powder and 10% ODS powder were $22.46 \pm 0.56\%$, $0.37 \pm 0.06\%$, $28.49 \pm 0.10\%$, $6.11 \pm 0.05\%$ and 42.58 ± 0.64 , respectively, $22.13 \pm 0.15\%$, $0.80 \pm 0.10\%$, $28.82 \pm 0.16\%$, $8.13 \pm 0.06\%$ and $40.12 \pm 0.32\%$, respectively and $22.53 \pm 0.11\%$, $0.80 \pm 0.10\%$, $28.21 \pm 0.06\%$, $8.03 \pm$

0.03% and $40.44 \pm 0.19\%$, respectively. The scores for overall acceptability of cakes incorporated with 10% FDS and ODS powder on an average for control cake, cake incorporated with 10%, FDS powder and 10% ODS powder were 8.87 ± 0.35 , 8.60 ± 0.50 , and 8.63 ± 0.49 , respectively. Scanning electron microscopic images and FTIR spectra of control bakery products and that incorporated with surimi powder were used to analyze the structural and functional properties, respectively of bakery products. Storage stability of control bakery product and that incorporated with surimi powder were analyzed by estimating the peroxide value, thiobarbituric acid value, free fatty acid value and microbial quality during storage and all parameters were within the acceptable limits during the entire storage period. The sensory evaluation of control bakery products, bakery products incorporated with FDS powder and that incorporated with ODS powder were estimated during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability of all the products decreased during their storage period. The obtained results also showed the supplementation of surimi powder into flour used for making bakery products at level up to 10% improved the nutritional parameters of the final bakery products. Moreover, inclusion of oven dried surimi powder in bakery products have almost similar acceptability as compared to bakery products incorporated with freeze dried surimi powder. Therefore, from the present study, it is evident that the incorporation of dried surimi in food products for fortification, especially of the bakery products up to the concentration of 10% can be recommended for commercial production.

CONTENT

CHAPTER NO.	TITLE	PAGE NO.
I.	INTRODUCTION	1 – 5
II.	REVIEW OF LITERATURE	6 - 22
	2.1 Surimi	7
	2.2 Composition of surimi	8
	2.3 Surimi based products	8
	2.4 Surimi powder	9
	2.5 Surimi powder based products	10
	2.6 Baking	11
	2.7 Bakery products	12
	2.8 Bread	12
	2.9 Biscuit	15
	2.10 Cake	16
	2.11 Fish based bakery products	18
	2.12 Emulsification	19
	2.13 Foaming	19
	2.14 Microstructure	20
	2.15 FTIR (Fourier Transform Infra Red Spectrophotometer)	20
	2.16 Indices of rancidity	21
III.	MATERIALS AND METHODS	23 -33
	3.1 Materials	23
	3.1.1 Raw materials	23
	3.1.2 Food ingredients	23
	3.1.3 Media and chemicals	23
	3.1.4 Instruments	24
	3.2 Methods	24
	3.2.1 Preparation of surimi powder by freeze drying	24

	3.2.2 Preparation of surimi powder by oven drying	25
	3.2.3 Preparation of bakery products	25
	3.2.3.1 Preparation of biscuit	25
	3.2.3.2 Preparation of bread	25
	3.2.3.3 Preparation of cake	26
	3.2.4 Analysis of functional properties	27
	3.2.4.1 Analysis of foaming capacity and stability	27
	3.2.4.2 Analysis of emulsion capacity and stability	27
	3.2.5 Proximate composition analysis of surimi and Bakery products	28
	3.2.5.1 Moisture	28
	3.2.5.2 Crude protein	28
	3.2.5.3 Crude fat	28
	3.2.5.4 Ash	28
	3.2.5.5 Minerals	28
	3.2.6 Analysis of structural changes by SEM (Scanning electron microscopy)	29
	3.2.7 Analysis of functional changes by FTIR (Fourier Transform Infra Red Spectrophotometer)	29
	3.2.8 Examination of shelf stability of bakery products by estimation of indices of rancidity	29
	3.2.8.1 Estimation of Thiobarbituric acid (TBA)	29
	3.2.8.2 Estimation of Peroxide value(PV)	29
	3.2.8.3 Estimation of Free fatty acid (FFA)	30
	3.2.9 Sensory evaluation of bakery products	31
	3.2.10 Analysis of microbial quality	31
	3.2.11. Amino acid composition	32

	3.3 Statistical analysis	32
IV.	RESULTS	34 -148
	4.1 Surimi powder	34
	4.1.1 Conditions for the preparation of surimi powder	34
	4.1.2 Functional properties of surimi powder	35
	4.1.3 Proximate composition of surimi powder	35
	4.1.4 Storage stability of surimi powder	36
	4.1.4.1 Thiobarbituric acid reactive substances value of surimi powder during storage	36
	4.1.4.2 Peroxide value of surimi powder during storage	37
	4.1.4.3 Free fatty acid in surimi powder during storage	38
	4.1.5 Microbial quality of Surimi powder during storage	39
	4.2 Biscuit	40
	4.2.1 Proximate composition of biscuit incorporated with surimi powder	41
	4.2.2 Sensory evaluation of biscuit incorporated with surimi powder	44
	4.2.3 Microstructure of biscuits during storage	46
	4.2.4 Storage stability of biscuits incorporated with surimi powder	48
	4.2.4.1 Thiobarbituric acid reactive substances value of biscuits incorporated with surimi powder during storage	48
	4.2.4.2 Peroxide value of biscuits incorporated with surimi powder during storage	49

	4.2.4.3 Free fatty acid in biscuits incorporated with surimi powder during storage	50
	4.2.5 Microbial quality of biscuits during storage	51
	4.2.6 Fourier Transform Infrared Spectroscopy of biscuits	52
	4.2.7. Organoleptic evaluation of biscuits during storage	75
	4.2.8 Amino acid composition of biscuits	79
	4.2.9 Minerals in biscuits	80
	4.3 Bread	81
	4.3.1 Proximate composition of bread incorporated with surimi powder	81
	4.3.2 Sensory evaluation of bread incorporated with surimi powder	83
	4.3.3 Microstructure of bread	87
	4.3.4 Storage stability of bread incorporated with surimi powder	89
	4.3.4.1 Thiobarbituric acid reactive substances value of bread incorporated with surimi powder during storage	89
	4.3.4.2 Peroxide value of bread incorporated with surimi powder during storage	90
	4.3.4.3 Free fatty acid in bread incorporated with surimi powder during storage	91
	4.3.5 Microbial quality of bread during storage	92
	4.3.6 Fourier Transform Infrared Spectroscopy of bread	93
	4.3.7 Organoleptic evaluation of bread during storage	108
	4.3.8 Amino acid composition of bread	111

	4.3.9 Minerals in bread	112
	4.4. Cake	113
	4.4.1 Proximate composition of cake with surimi powder	113
	4.4.2 Sensory evaluation of cakes incorporated with surimi powder	115
	4.4.3 Microstructure of cake	119
	4.4.4 Storage stability of cakes incorporated with surimi powder	121
	4.4.4.1 Thiobarbituric acid reactive substances value of cakes incorporated with surimi powder during storage	121
	4.4.4.2 Peroxide value of cakes incorporated with surimi powder during storage	122
	4.4.4.3 Free fatty acid in cakes incorporated with surimi powder during storage	123
	4.4.5 Microbial quality of cakes during storage	124
	4.4.6 Fourier Transform Infrared Spectroscopy of cakes	125
	4.4.7 Organoleptic evaluation of cake during storage	143
	4.4.8 Amino acid composition of cakes	146
	4.4.9 Minerals in cakes	147
V	DISCUSSION	149 – 167
	5.1 Surimi powder	149
	5.2 Biscuit	151
	5.3 Bread	156
	5.4 Cake	161
	5.5 Microstructure of bakery products	166
VI	SUMMARY AND CONCLUSION	168

VII	REFERENCES	185
------------	-------------------	------------

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
3.1	Media, methodology, incubation period and time adopted for the enumeration of microbes	32
4.1	Functional properties of surimi powder	35
4.2	Assignment of FTIR Peaks – Ingredients and biscuits	61
4.3	Organoleptic evaluation of control biscuit during storage	76
4.4	Organoleptic evaluation of biscuit incorporated with FDS powder during storage	77
4.5	Organoleptic evaluation of biscuit incorporated with ODS powder during storage	78
4.6	Amino acid composition of biscuits	79
4.7	Minerals in biscuits	80
4.8	Assignment of FTIR Peaks – Ingredients and bread	96
4.9	Organoleptic evaluation of control bread during storage	109
4.10	Organoleptic evaluation of FDS bread during storage	109
4.11	Organoleptic evaluation of ODS bread during storage	110
4.12	Amino acid composition of bread	111
4.13	Minerals in bread	112
4.14	Assignment of FTIR Peaks – Ingredients and cakes	129
4.15	Organoleptic evaluation of control cake during storage	144

4.16	Organoleptic evaluation of cake incorporated with FDS powder during storage	144
4.17	Organoleptic evaluation of cake incorporated with ODS powder during storage	145
4.18	Amino acid composition of cakes	146
4.19	Minerals in cakes	147

LIST OF PLATES

Plate No.	Title	Page No.
I	Biscuits incorporated with surimi powder	43
II	Bread incorporated with surimi powder	86
III	Cakes incorporated with surimi powder	118

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
4.1	Proximate composition ODS and FDS powder	36
4.2	TBARS value of surimi powder	37
4.3	Peroxide value of surimi powder	38
4.4	Free fatty acid in surimi powder	39
4.5	Total plate count of surimi powder	40
4.6	Proximate composition of biscuits incorporated with FDS powder	41
4.7	Proximate composition of biscuits incorporated with ODS powder	42
4.8	Sensory scores of biscuit incorporated with FDS powder	44
4.9	Sensory evaluation of biscuit incorporated with ODS powder	45
4.10	SEM image of control biscuit	46
4.11	SEM image of FDS biscuit	47
4.12	SEM image of ODS biscuit	47
4.13	TBARS value of biscuits during storage	48
4.14	Peroxide value of biscuits during storage	49
4.15	Free fatty acids in biscuits during storage	50
4.16	Total plate count of biscuits	51
4.17	FTIR analysis of cocoa powder	52
4.18	FTIR analysis of Maida	53
4.19	FTIR analysis of Sugar	54
4.20	FTIR analysis of Shortening	55
4.21	FTIR analysis of FDS powder	56
4.22	FTIR analysis of ODS powder	57
4.23	FTIR analysis of Control biscuit	58
4.24	FTIR analysis of FDS Biscuit	59

4.25	FTIR analysis of ODS Biscuit	60
4.26	Proximate composition of bread with FDS powder	82
4.27	Proximate composition of bread with ODS powder	83
4.28	Sensory scores of bread incorporated with FDS powder	84
4.29	Sensory evaluation of bread incorporated with ODS powder	85
4.30	SEM image of control bread	87
4.31	SEM image of FDS bread	88
4.32	SEM image of ODS bread	88
4.33	TBARS value of bread during storage	89
4.34	Peroxide value of bread during storage	90
4.35	Free fatty acid in bread during storage	91
4.36	Total plate count of bread.	92
4.37	FTIR analysis of Control bread	93
4.38	FTIR analysis of FDS bread	94
4.39	FTIR analysis of ODS bread	95
4.40	Proximate composition of cake with FDS powder	114
4.41	Proximate composition of cake with ODS powder	115
4.42	Sensory scores of cakes incorporated with FDS powder	116
4.43	Sensory scores of cakes incorporated with ODS powder	117
4.44	SEM image of control cake	119
4.45	SEM image of FDS cake	120
4.46	SEM image of ODS cake	120
4.47	TBARS value of cakes during storage	121
4.48	Peroxide value of cakes during storage	122
4.49	Free fatty acid in cakes during storage	123
4.50	Total plate count of cakes	124
4.51	FTIR analysis of oil	125
4.52	FTIR analysis of control cake	126
4.53	FTIR analysis of FDS cake	127
4.54	FTIR analysis of ODS cake	128

I. INTRODUCTION

Marine sector is one of the key sources of protein in human diet. In addition to being tasty constituents of meals and food products, fish and seafood products also have high nutritional value and contain beneficial amounts of protein, lipids as well as essential minerals and vitamins (Sampels, 2014). Owing to the spreading awareness of its health effects, seafood consumption is generally increasing in many parts of the world, particularly for coastal communities. In many places, marine protein is the only type that people can self-harvest, often throughout the year. In 2017, the marine fish landings in India recorded for about 3.83 million tonnes. Compared to 2016, the landings have a marginal increase of 5.6%. Kerala has over taken Karnataka to emerge as the third largest producer. Gujarat ranked first among the maritime states with 7.86 lakh tonnes of marine fish landings for the fifth consecutive year followed by Tamil Nadu with 6.55 lakh tones in 2017. In marine fish landings, the pelagic fin fishes dominated and contributed 54% of the landings followed by demersal fin fishes (26.8%), crustaceans (12.6%) and mollusks (6.6%). Indian oil sardine, mackerel, ribbon fish in pelagic fin fishes, lesser sardines and Bombay duck. Bulls eye (*Priacanthus* spp.), threadfin breams, croakers, silver bellies and catfishes dominated in demersal fin fishes whereas prawns, crabs and lobsters and squids, cuttle fish, clams and oysters contributed a major portion in crustaceans and molluscs respectively (Central Marine Fisheries Research Institute, (CMFRI) 2017). During the year 2017-18, India has exported 13,77,244 MT of seafood worth US\$ 7.08 billion. USA and South East Asia continued to be the major import markets of Indian seafood where the major export item was frozen shrimp

which accounted for a share of 41.10% in quantity and 68.46% of the total USD earnings. It was followed by frozen fish, frozen squid, chilled items, frozen cuttlefish, dried items, live items and other items (Marine Products Export Development Authority (MPEDA), 2018).

However, some of the marine fishes are undersized or underutilized as they are not aesthetically pleasing to consumers and traditionally were thrown back to sea but now these fishes can be converted into value added products due to their high protein content. Regular fish consumption is generally accepted as part of a healthy diet and is backed up by strong scientific evidence. Fish have high protein content compared to other animal meat from terrestrial sources and a lower feed conversion rate (FCR) than most terrestrial animals and more quantities of protein can be produced from fish (Sampels, 2014; Henchion et al., 2017). Furthermore, fish protein is highly digestible and rich in essential amino acids that are limited in animal sourced protein including methionine (6.5% compared to 5.7% of total essential amino acids in fish compared to animal meat) and lysine (19.6% compared to 19.0% of total essential amino acids in fish compared to animal meat) (Tacon and Metian, 2013). However, the off fishy flavour limits its acceptability and applicability. In order to remove the barriers in using fish protein extensively to develop new fishery products, the odouriferous components of fish must be removed. Research is being done to develop enzymes that can enhance the smell of ingredients and products made by residual raw materials from the fishing industry (Graven, 2017). In order to increase the acceptability, odourless amberjack has been developed in Japan (Towers, 2016). Surimi is the concentrated myofibrillar protein extracted from

fish flesh by washing minced meat that has been separated from bones, skin, and gut (Okada, 1992) and the odouriferous compounds in fish are lost during the manufacturing process, thereby making it odourless. Sodium-reduced fried fish cakes were prepared with surimi and its quality was studied by Hwang et al. (2013). Nevertheless, literatures regarding sweetened and bakery products incorporated with fish are not available although bakery products viz. cakes, bread and biscuits are popular in the domestic and international markets.

Fish based ready to eat products are available in several countries like China, Thailand and Korea, and are prepared by various processing technologies like baking, vacuum drying, steaming and frying. Some important nutritious fish based foods include fish chips, squid rings, fish crackers, shredded squids, prawn crackers, surimi powder and surimi based dried snack foods having shelf life of 3 to 4 months but the fish based bakery products are not much popular. If fish based bakery products are made available in India, it will lead to the better utilization of fishery resources and will also reform the food habits resulting a healthier population.

Bakery is a traditional activity that occupies an important place in food processing industry. The bakery manufacturers in India can be categorized into the three broad sectors viz. bread, biscuits and cake. About 1.3 million tonnes of the bakery products in India comes from the organized sector out of 3 million tonnes, while the remaining comes from the small-scale local manufacturers' and are unorganized (Food processing bazaar, 2017).

Most of the children are not the beneficiaries of the healthier diet obtained from fish and fishery products; if the nutritious components are not incorporated in children's favorite foods, such as biscuits, or are not used as main components of daily foods. Biscuits are the most popular bakery products due to their unique taste, longer shelf life, easy availability, and convenience (Florence et al., 2014). Compared to fish products, the nutritional content of biscuits is very poor. The commonly used raw material to make biscuits is wheat flour with high gluten content (Agrahar-Murugkar et al., 2015). Therefore, there is a requirement to find an alternative solution that can enhance the nutritional content of wheat flour products by fortification with some amount of surimi powder.

Bakery products owe their popularity to their richness and sweetness. They can be sold and presented in many forms as specialty goods refrigerated or at ambient temperature. Cheaper marine fish with more white muscle protein can be utilized to obtain surimi that may be easily incorporated into various baked products to substitute paste for flour. However, the use of the surimi as a source of protein will also influence the textural properties and aroma of bakery products. The impact of the surimi also needs to be assessed in terms of baking performance, consumer acceptability, and shelf life which are considered to be the key factors to their successful employment. In this study, surimi powder was added to substitute flour in the bakery products. The effects of adding the surimi on the qualities of bakery products and their shelf life after storage at ambient temperature were investigated. The information has been given regarding the evaluation of the acceptability of bakery products with the addition of surimi. The results of the study will be useful for

the food processors to decide on the optimum processing conditions for bakery products using surimi powder and also lead to better utilization of fish by increasing the product diversity. The objectives of the present study are given below.

1. To optimize the conditions for the preparation of surimi powder.
2. To examine the functional properties and shelf stability of surimi powder.
3. To optimize the proportions for the formulation of the bakery products with surimi powder.
4. To study the nutritional and shelf stability of formulated bakery products.

II. REVIEW OF LITERATURE

Relation between food and health has an increasing impact on food innovation, mainly due to the popularity of the concept of functional foods. General concept of functional food comes from the practice of using nutrition knowledge at food product level to improve health of the consumers. Often, overweight people have a craving for sweets and find it extremely difficult to keep away from eating high calorie products. Therefore, new sweetened products need to be developed, which have all the health-promoting properties of foods, but with taste and look like the conventional foods that are widely accepted and regularly consumed by the public, and fortification of bakery products with different kinds of nutrients is a common trend and protein fortification is gaining immense importance (Kârkliòa et al., 2012).

Animal proteins are the best source of proteins, where it supplies the body with essential amino acids. Meat is considered as the main source of proteins which can be obtained from poultry, beef, pork, fish and mutton etc. (Ministry of Agriculture, Malasiya, 2009; Hoda and Gezery, 2017).

The common concepts relevant to nutritional, structural, functional and stability characteristics of bakery products formulated with surimi powder are given under the following headings

1. Surimi
2. Composition of surimi
3. Surimi based products
4. Surimi powder

5. Surimi powder based products
6. Baking
7. Bakery products
8. Bread
9. Biscuit
10. Cake
11. Fish based bakery products
12. Emulsification
13. Foaming
14. Microstructure
15. FTIR
16. Indices of rancidity

2.1 Surimi

Origin of surimi, a uniquely functional food ingredient prepared from fish proteins is believed to be in Japan and is also used in as a base product in several seafood products for centuries. It consists of separated concentrated proteins from fish that are refined by deheading, degutting and then mincing the fish flesh, washing and removing water repeatedly, and finally freezing the remaining protein (Xiong, 2004). It is usually prepared from fishes with high quantities of light meat compared to fishes with dark flesh. Alaska pollock, threadfin bream, croaker, Pacific whiting, big eye snapper, mackerel and sardine are some of the widely used species of fishes for surimi production worldwide (Morrissey and Tan, 2000). According to MPEDA (2019), the different types of surimi in India were SA, AA, A KA and C

lizardfish surimi, SA, AA, A KA and C big eye surimi, KA and C reef cod surimi, SSSA, SSA, SA, AA, AKA and C Japanese threadfin bream surimi, SSSA, SSA, SA, AA, AKA and C croaker surimi and KA & C ribbon fish surimi whereas the exported surimi based products were crab bite imitation crab flake (chunks), imitation crab stick (filament), imitation crab stick (solid), imitation shrimp and imitation lobster.

2.2 Composition of surimi

The proximate composition of SSA grade surimi was studied by Chuapoe huk et al. (2001). Surimi manufactured with two species of marine fishes were analysed over one year in terms of chemical composition, calories, amino acid profiles and mercury levels by Mira and Lanfer-Marquez (2005). Yield and composition of surimi from pacific whiting was studied by Lee et al. (2006). Changes in proximate composition of thornback ray surimi during washing and frozen storage was studied by Turan and Sönmez (2010). Yathavamoorthi et al. (2012) analysed the proximate composition of common carp surimi stored in ice for different periods. Chemical compositions of frozen surimi were analyzed by Wei et al. (2018) for different grades of surimi viz. A, AA, FA and SA.

2.3 Surimi based products

Surimi is an intermediate product used in the preparation of a variety of ready-to-eat seafood commodities, known as surimi-based products and includes products such as sticks, crumbs, slices and lobster tails-like (Ducept et al., 2012; Giusti et al., 2017). Kok and Park (2007) attempted to extend the shelf life of set fish ball, an extruded surimi-based product by reducing oversetting conditions and

microbial counts. Lempek et al. (2007) evaluated the influence of soy protein, potato starch and heating temperature on the texture of emulsified sausage processed from Argentine croaker (*Umbrina canosa*) surimi. Jeyakumari et al. (2016) prepared restructured products from pangasius surimi and analysed their qualities under chilled storage.

2.4 Surimi powder

Since surimi had to be kept at -25°C or below until usage (Toyoda et al. 1992), it must be stored in frozen conditions resulting in higher costs (Santana et al., 2012). Moreover, surimi also has a moisture content of about 83% which needs high cost for handling, distribution, and space to store (Parvathy and Sajan 2011), whereas surimi powder does not require frozen storage, which lowers the distribution and storage costs relative to frozen surimi and also were easy to handle and can be used in dry mix applications (Niki et al. 1992).

The physicochemical properties of surimi powder have been investigated previously and optimization of the drying process was attempted (Niki et al., 1992; Huda et al., 2000b, Huda et al., 2001a; Shaviklo et al., 2010b). Matsuda (1981) dried carp myofibrils using a freeze dryer at a temperature of -40°C and a vacuum pressure of 0.1–0.02 Torr. According to Menon and Mujumdar (1987), oven drying processes involved heating, drying, and baking. However, freeze drying was considered to be the best method of drying for inhibiting protein denaturation as compared to other drying methods, as it occurs at a low temperature and the transition of material from fully hydrated to completely dehydrated occurs rapidly

(Liapis, 1987). Freeze drying is usually considered to be the method with minimal damaging for drying proteins. However, it is also the most expensive method than the others due to the energy required to keep the vacuum condition and the low temperature (Ratti, 2008). Chavan et al. (2008) used oven drying, a low cost technology for developing dried fish protein. Huda et al. (2000a) studied the effect of oven drying temperatures such as 50, 60, and 70°C on the functional properties of fish protein concentrate from lizardfish. Huda et al. (2000b) produced surimi powder using conventional oven at 60°C and reported the effect of cryo-protectants (sucrose and phosphate) on the functional properties of the product.

The difference between frozen surimi and surimi powder is that surimi powder can be kept at ambient temperature without the requirement of frozen storage (Meenachi, 2016). Majumder et al. (2017) stated that dry mixing of surimi powder could help industries to modify the formulation of surimi-derived products, thereby enabling more homogenous blends and easier protein standardization. The authors also prepared surimi powder from tilapia (*Oreochromis mossambicus*) and studied its physico-chemical properties and proximate composition.

2.5 Surimi powder based products

The nutritional quality and physicochemical properties of surimi powder make it ideal for producing formulated seafood and also other food products (Park and Lin 2005). Since the 1990s, the application of surimi powder in food products are growing, including rice-fish snacks (Gogoi et al. 1996), fish crackers (Huda et al. 2001; and Huda et al. 2009), fish balls (Huda et al. 2003), corn-fish snacks (Shaviklo

et al. 2010a), fish cutlet mixes (Shaviklo et al. 2011) and sausage (Santana et al., 2013)

Huda et al., (2001) evaluated freeze dried surimi from threadfin bream (*Nemipterus sp.*), purple-spotted big eye (*Priacanthus tayenus*), and lizardfish (*Saurida sp.*) Shaviklo et al. (2010b) found that freeze-dried surimi made from saithe (*Pollachius virens*) that was treated with cryoprotectant had better gelation property. Chung et al. (2000) evaluated the use of freeze dried mackerel proteins as a binder for restructured meat and found that 0.1% reducing agents improved their binding ability as measured by tensile strength. Oven dried surimi powder was used to substitute tapioca flour in the formulation of Indonesian traditional crackers by Huda et al. (2001). El-Kholie (2014) used crushed homogenized dried surimi from common carp (*Cyprinus carpio*) at 10, 20 and 30% to fortify baby food. Santana et al. (2013) developed fish sausage made with 100% threadfin bream (*Nemipterus japonicus*) surimi powder (SP100), a mix of 50% surimi powder and 50% frozen surimi (SP50), and a control (100% frozen surimi) and studied the physicochemical properties and sensory characteristics of the product. Guo et al. (2018) investigated the effects of heating method and addition of microbial transglutaminase on the properties of gels made from vacuum-freeze dried silver carp surimi.

2.6 Baking

There are records of baking bread from 2600-2100 B.C. by Egyptians, who were believed to have learned the skill from the Babylonians (Pfister, 2013). Baking is a dry method of cookery in which food items are prepared and produced, baked in

dry heat in a standard baking oven, or forced air convector oven which reduces the time the food takes to cook. Baking occurs due to the convection and conduction of heat in a dry atmosphere, within a closed or confined chamber and the temperature of the baking process is directly related to the nature of the food to be baked. High-sugar foods require a lower temperature to prevent caramelisation while high-fat foods such as pastry require a much higher temperature (Foote, 1996). According to Snack Food & Wholesale Bakery (2019), bakery products include categories like bars, breads (bagels, buns, rolls, biscuits and loaf breads), desserts (cakes, cheesecakes and pies), cookies, muffins, snack cakes, pizza, sweet goods (doughnuts, sweet rolls, Danish, cinnamon rolls and coffee cake) and tortillas.

2.7 Bakery products

Baked products are usually used to incorporate new sources of functional compounds to improve the quality (Ktenioudaki et al., 2013). Saranraj and Geetha (2012) accounted on the microbial spoilage of bakery products and its control by preservatives. Kaur and Kochhar (2017) evaluated the sensory and proximate profile of value added bakery products prepared using bael (*Aegle marmelos*) and *Stevia* powder. Mishra et al. (2018) developed and standardized baked value added products by using Indian horse chestnut (*Aesculus indica*) flour and analysed the proximate composition of the products.

2.8 Bread

Bread has always been one among the most popular and appealing food products because of its superior sensorial, nutritional and textural characteristics,

ready to eat convenience and cost competitiveness (Giannou and Tzia, 2007). Bread making is a temperature dependent process with two major steps consisting of fermentation, in which CO₂ production linked with yeast activity leads to porous dough structure with the development of dough volume, and baking during which yeast activity is ended and the bread structure is finalized (Balarabe et al., 2017). Consumers' demand for functional foods is increasing, owing to their direct contribution in preventing nutrition-related diseases (Venturi et al., 2017; Ahmad et al., 2018). Hence, supplementing bread with nutritious ingredients in order to boost its physical and nutritional properties is very trendy in these modern times (Das et al., 2016; Ahmad et al., 2018).

Fang (2008) studied the physico-chemical and organoleptic characteristics of wheat bread substituted with different percentages of pumpkin flour (*Cucurbita moschata*). Oxidative stability of the whole wheat bread packed in modified atmosphere (nitrogen) using vacuum grade plastic bags on storage for up to 5 weeks was reported (Jensen et al., 2011). Beloved et al. (2012) evaluated proximate composition and shelf-life of different brands of bread obtained from the market in Ghana during a storage period of 24 days. Tiimub (2013) evaluated the proximate compositions of three brands of bread available on the Ghanaian market under different packaging conditions.

Odedeji et al. (2014) analysed the proximate composition and acceptability of bread produced from blends of soy-cheese and wheat flour using the blend ratios 95:5, 90:10, 85:15 and 80:20. Ho et al. (2014) evaluated the quality of bread prepared by incorporation of the banana pseudo-stem flour and the composite

bread containing hydrocolloids during storage. Bhise and Kaur (2014) incorporated polyols such as glycerol, sorbitol and mannitol at 2, 4 and 6% in flour for bread making and studied their effect on textural properties, bread making quality and sensory acceptability. Nutritional, microbiological and sensory quality of bread produced from wheat and potato flour blends were examined by Ijah et al. (2014) and found that bread baked from 95% wheat flour and 5% Irish potato flour or sweet potato flour had higher acceptability.

Unachukwu and Nwakanma (2015) collected 30 bread samples from different vendors in Enugu and investigated the fungi associated with the spoilage of bread for 7 days. Latif et al. (2005) prepared bread from wheat flour by adding different additives and reported the quality changes during 10 days of storage. Physico-chemical characteristics and sensory properties of bread formulated with lemon pomace fibre were examined (Chang et al., 2015). Cakes of cumin (*Cuminum cyminum* L.) and caraway (*Carum carvi* L.) after oil extraction were used to formulate protein bread at different levels (2, 4 and 6%) and the effect on bread properties were reported by Ahmad et al. (2018). Baiano et al. (2015) enriched bread with phenolic aqueous extracts from vegetable wastes from chicory, cabbage, celery, fennel, olive leaf, or grape marc wastes obtained through microwave-assisted extraction. Ravimannan et al. (2016) observed the fungi associated with spoilage of bread and Ravimannan (2016) reported on the microbial profile of bread during storage.

The physico-chemical and sensory quality of bread produced using different indigenous yeast isolates were evaluated and the effect on overall quality of the

product was studied (Balarabe et al., 2017). Jain et al. (2017) formulated bread by incorporating wheat grass powder into it and studied its nutrient composition, physicochemical properties and sensory analysis. Dried mushroom (*Plerotus ostreatus* and *Calocybe indica*) powder was used to replace wheat flour in bread formulation at 0%, 5%, 10%, 15% and 20% and the proximate and mineral composition of the fortified bread were analysed (Oyetayo and Oyedeji, 2017).

2.9 Biscuit

Biscuit is one of the snacks preferred by all the segments of society throughout the world. Biscuits are ready-to-eat quick snacks with variety, versatility, flavour and relatively longer shelf-life and are the most popular bakery items (Akubor 2003; Kumar et al., 2015). The protein fortified biscuits contain nutrients in concentrated form and can provide essential amino acids which could be obtained by using various protein rich non wheat ingredients added to the flour (Hoojjat and Zabik, 1984). Biscuit can be prepared by substituting some amount of wheat flour by adding some ingredients to increase nutritional value and influence physical, chemical and sensory attributes (Silky, 2014).

El-Sharnouby et al. (2011) studied the effect of partial replacement of wheat flour with mixture of wheat bran and date palm fruit powder on the rheological properties of the biscuit dough and the nutritional quality of biscuits. Kârkliòa et al. (2012) attempted to increase the nutritional value of biscuits by substituting wheat flour with Jerusalem artichoke powder and powder of cocoa bean shells.

Ernst et al. (2014) prepared biscuits with dried beef, another with added soybean flour, and another using wheat biscuit and used in a randomized feeding intervention in drug-naïve, HIV-infected rural Kenyan women and their children and also examined and compared the nutritional contents of the different types of biscuit.

Jaiswal et al. (2015) evaluated the sensory and textural quality of chicken meat biscuits prepared by replacing refined wheat flour with different levels (40%, 50% and 60%) of chicken meat powder prepared by mincing and dehydration of chicken meat. Kumar et al. (2015) prepared fibre-enriched chicken meat biscuits incorporated with wheat bran and oat bran at three different levels viz. 3%, 5.0% and 7% and evaluated quality attributes and storage stability of the products for a period of 180 days.

Hoda and Gezery (2017) incorporated whey protein and okara into biscuits at 10% and compared with school's biscuits for the Chemical and nutritional characteristics. Homann et al. (2017) developed cricket (*Acheta domesticus*) biscuits suitable for school feeding programmes and tested the acceptability of biscuits in Kenyan school children, in comparison with a similar biscuit with milk.

Stellamaris et al. (2018) formulated a nutrient-rich complementary biscuit for children between eight months and fifty nine months with a composite flour of 32% banana flour, 24% soya bean flour, 20% pumpkin seed flour and 24% wheat flour.

2.10 Cake

Cakes are one of the most consumed bakery products owing to the unique products and are always used in festivals as well as in joyous celebrations (Hafez,

2012; Hussain and Al-Oulabi, 2009; Zhang et al., 2012; and Khalifa et al., 2015). Cupcake were reportedly evolved in the United States in the 19th century, and was revolutionary due to the amount of time it saved in the kitchen and are portion-controlled, easy to make in batches, portable, open to lots of decorating strategies, tasty and less expensive to make. However, the use of white flour derived from the processing of whole wheat grain, aimed at improving the aesthetic value of white bread, has also led to the drastic reduction in the nutritional density and fibre content as compared to bread made from whole grain cereals. Recently, consumers' awareness of the need to eat high quality and healthy functional foods, incorporated with ingredients that provide additional health benefits beyond the basic nutritional requirements, is growing leading to the trend of producing specialty bakery products made from whole grain flour and other functional ingredients (Rebecca et al., 2016).

Alyas et al. (2006) prepared yellow cake using red palm shortening, red palm margarine and a commercial margarine at the ratio 26:15:59 and examined the storage stability. Demirkol (2007) studied the variation of physical properties of different cake formulations during baking in different methods such as using microwave and infrared microwave combination ovens. Sozer et al. (2010) formulated cakes using gum, modified starch and enzyme technology and studied its shelf life stability. Physicochemical and sensory properties of cake supplemented with marjoram as partially substituted of flour at different levels (1, 2 and 3 %) were observed by Hafez (2012).

Khalifa et al. (2015) partially substituted wheat flour by two varieties of potato peels at 5% - 20% and prepared cupcake and studied the proximate chemical composition, physical characteristics, rheological parameters, total phenolic compounds and relative antioxidant activity in addition to quality parameters such as thiobarbituric acid, sensory evaluation and microbiological attributes of the products during storage. Rebecca et al. (2016) attempted to fortify cupcakes with cereals and pulses such as corn flour, powdered green gram, powdered oats, powdered peanuts and powdered soybeans and studied the nutritional and sensory quality of the products.

Höglund et al. (2017) fortified muffins with rape seed oil and whey powder and investigated the fat and protein content and reported their nutritional value, sensory properties and physical parameters of the products. El-Fadaly et al. (2017) collected chocolate cake samples from different sites of local markets of Damietta and Dakahlia and evaluated the microbial quality of the products.

2.11 Fish based bakery products

With the trends toward malnutrition, nutritious, healthy eating and developments of nutritional food, the application of fish protein in biscuit baking is a viable current alternative (Abraha et al., 2018b).

The impact of fortification of biscuits with carp fish protein concentrate (CFPC) and shark fish protein concentrate (SFPC) on nutritional value and overall acceptability of the products were evaluated (Mohamed et al., 2014).

Abraha et al. (2018a) evaluated the physico-chemical and nutritional qualities of biscuit produced from sturgeon fillet protein concentrate (SFPC) based on gross chemical composition, effects of SFPC incorporation, and storage stability for six months in which SFPC was used in production of biscuits by replacing low gluten wheat flour by 5%, 7% and 10%. Pi et al. (2017) substituted 30% of the flour with dolphinfish (*Coryphaena hippurus*) and unicorn leatherjacket (*Aluterus monoceros*) paste in a cake recipe and evaluated the quality and shelf life of fish chiffon cakes stored at 4°C and 25°C by examining the proximate composition, free amino acid, aerobic plate count, total volatile basic nitrogen, texture profile and sensory evaluation. Biscuits produced from low gluten wheat flour were fortified with sturgeon fillet powder (SFP) in various mixing ratios (100:0, 95:5, 93:7, and 90:10, respectively) and the nutritional and proximate composition were studied (Abraha et al., 2018b)

2.12 Emulsification

The optimum emulsion capacity of proteins occurs when the hydrophilic and hydrophobic proportions are in balance (Damodaran, 1996; Meenachi, 2016). Denaturation of the protein may decrease the emulsification capacity of surimi powder; however addition of sugar as a cryoprotectant maintains the hydrophilic residues after drying (Matsumoto and Noguchi, 1992; Meenachi, 2016).

2.13 Foaming

Foams are defined as a dispersed state of gas in liquid or liquid in gas materials (Foegeding and Davis, 2011; Meenachi, 2016). The strength of the protein

in trapping gases influences the foaming properties of the protein (Belitz et al., 2009; Meenachi, 2016). Better foaming properties of surimi powder were related to the stability of the fish protein (Huda et al., 2001; Shaviklo et al., 2010c; Meenachi, 2016).

2.14 Microstructure

Microscopic study of low-protein and gluten-free breads were performed using scanning electron microscopy (Ahlborn et al., 2005). Datta et al. (2006) observed the porous structure in breads baked using various heating modes such as microwave–infrared, microwave–jet impingement and jet impingement using scanning electron microscopy. Shyu and Sung (2010) observed the microscopic image of sponge cake added with polyglutamic acid.

Filipčev et al. (2011) evaluated the microstructural properties of dough and honey biscuits enriched with buckwheat and rye. Jongsutjarittam and Charoenrein (2013) studied the influence of waxy rice flour substitution for wheat flour on characteristics of batter and freeze-thawed cake.

Mamat and Hill (2012) studied the effect of fat types on structural properties of dough and semi-sweet biscuit using scanning electron microscopy. Marina et al. (2016) studied the effect of incorporation of avocado (*Persea americana*) puree on the physical and microstructure of butter cake. Skendi et al. (2018) studied the effect of acorn meal–water combinations on fine structure of gluten-free bread using scanning electron microscopy. Ali et al. (2018) investigated the differences in

microstructure of dough after egg replacement by black gram flour using the scan-electron microscopy.

2.15 FTIR (Fourier Transform Infra Red Spectrophotometer)

Sivam et al. (2011) reported on the application of FTIR for the study of biopolymers in breads fortified with fibre and polyphenols. The interactions between blackcurrant polyphenols and pectin added to bread as well as different bread components in model bread systems were reported (Sivam et al., 2012). Interactions between Serish root inulin and the biopolymer types of wheat flour namely gluten, starch and phospholipid, were investigated by Pourfarzad et al. (2015) in different model systems using Fourier transform infrared (FTIR) spectroscopy and analysed the underlying physical mechanism by which inulin impacts dough and bread properties. Skendi et al. (2018) prepared gluten-free breads from rice flour and corn starch at a constant ratio 1:1, incorporated with acorn meal addition (5, 15, 25%), at three levels of water (65, 70, 75%) and analysed the FTIR spectrum of the product.

2.16 Indices of rancidity

Analysis of rancidity determines the level of oxidation in a sample. When lipids undergo rancidity, its nutritional value could be compromised, and the lipids will impart a rancid taste and odour. Hence, proper rancidity estimation is an essential component in determining the shelf life of a food product. Peroxide value determines the number of peroxides in the lipids and is the initial indicators of lipid oxidation and will continue to react and produce secondary products such as

aldehydes. Free Fatty Acids (FFA) determine the number of fatty acids that have been liberated from the triglyceride structure and the presence of free fatty acids can impart strong flavours and odours at relatively low levels. TBA value measures the aldehydes (primarily malondialdehyde) created during lipid oxidation and this analysis is widely used as the whole sample can be analyzed rather than just extracted lipids (Eurofins, 2019).

The oxidative stability of whole wheat bread was evaluated by measuring several different markers of oxidation by Jensen et al. (2011). Verardo et al. (2010) incorporated air-classified barley flours into bakery products and studied their effect on the lipid stability of the product. Peroxide and TBA value of different samples (coated and uncoated ground flaxseed) over time were measured and were used to prepare taftoon bread (Roozegar et al., 2014). Alemán et al. (2015) incorporated heme iron ingredient into chocolate cream used to fill sandwich-type cookies and evaluated its effectiveness on the oxidative stability of the product. Caruso et al. (2016) studied the oxidative stability of bakery products. Osuna et al. (2018) effects of ascorbic acid and α -tocopherol on the oxidative stability of bread made with whole flours and vegetable oils.

III. MATERIALS AND METHODS

3.1 Materials

3.1.1 Raw materials

Commercially available itoyori surimi (20 kg) prepared from *Nemipterus* species was procured from Gadre Marine Export Private Limited, Baikady village, Brahmavar, Udupi, Karnataka. Itoyori surimi was selected due to the availability of raw material (fresh fish) along the Indian coast and also as the whiteness of surimi from this species is the highest among commercially available surimi in India. The frozen sample was packed with gel ice and was transported to the laboratory at Fisheries College Research Institute, Thoothukudi and was stored at -25°C for further use.

3.1.2 Food ingredients

Food grade ingredients viz. cocoa powder, maida, refined sunflower oil, shortening (vanaspathi), yeast, egg, baking powder, baking soda and sugar with FSSAI approval were used for the preparation of bakery products and they were obtained from the local super market.

3.1.3 Media and Chemicals

Chemicals used for the analysis of biochemical composition were of analytical (AR) grade. Microbiological media such as Plate Count Agar (PCA) and potato dextrose agar were purchased from Hi-Media Laboratories India Pvt. Ltd., Mumbai. Hydrochloric acid, sulfuric acid, TBA reagent, Tris HCl buffer, copper sulphate, sodium carbonate, sodium hydroxide, sodium potassium tartarate, sodium thiocyanate, petroleum ether, glacial acetic acid, potassium iodide, chloroform and

meta cresol purple, bromocresol green, methyl red were purchased from Merck India Ltd., Chennai, India.

3.1.4 Instruments

REVA 60 FFD Freeze Drying System (Ref-Vac consultancy, Vadodara, India), Electronic balance (Model CP 2250, Sartorius Mechatronics, Germany), laminar flow chamber (Klenzaid, India), autoclave (Secor, New Delhi, India), incubator (Secor, New Delhi, India), iD3 ATR–FTIR Spectrometer (Is5 NICOLET, Thermo Scientific, USA), Scanning electron microscope (ZEISS sigma VP, Germany), UV-Vis spectrophotometer (Jasco, Japan), Hot air oven (Technico, India), homogenizer (Remi, India), baking oven (Arunrega, India), KEL- PLUS digestion and distillation apparatus (Pelican equipments, Chennai), SOCS plus – SCS 4 (Pelican equipments, Chennai), and muffle furnace (Technico, India) were used. Pestle and mortar, distillation unit, water bath (Dalal, Chennai, India), sterile pipettes and incubator (Secor, New Delhi, India) were also used for the study.

3.2 Methods

3.2.1 Preparation of surimi powder by freeze drying

In this method, frozen surimi slices (10 cm length, 5 cm width, 0.5 cm thickness) were frozen in a blast freezer at - 23°C for at least 24 h, and then placed in the drying chamber of REVA 60 FFD Freeze Drying System at a vacuum pressure of 0.500 mbar in the chamber and ultimate condenser temperature was - 45°C. The dryer was activated and run for 8 h until the moisture inside the sample was evaporated. The dried samples were powdered using a domestic mixer and

sieved. The resulting freeze dried surimi (FDS) powder was packed in 100 g aluminium lined pouches and stored at ambient temperature for further use.

3.2.2 Preparation of surimi powder by oven drying

For oven drying, frozen surimi slices were thawed overnight at 4°C in a refrigerator and placed inside the hot air oven and the drying temperature was standardized by drying at different temperatures between 45 and 60°C and then was optimized at $55 \pm 5^\circ\text{C}$, observing the temperature at which the product gets discoloured or charred. The dried samples were milled and sieved using size 425 Gm No. 40- mm screen mesh. The resulting oven dried surimi (ODS) powder was packed in aluminium lined pouches and stored at ambient temperature for further use.

3.2.3. Preparation of bakery products

3.2.3.1 Preparation of biscuit

Biscuits were prepared with flour containing maida and cocoa powder as control. All the ingredients viz. maida (100 g), sugar (50 g), shortening (vanaspathi- 60 g) and cocoa powder (10 g) were weighed. Sugar and shortening were mixed thoroughly. All the other ingredients were sifted together and added to the sugar-shortening mix to form a homogenous mass. Small balls were made from this blend and rolled into a sheet and was cut. It was placed in a baking pan greased with vegetable oil and baked at 160°C for 15 min. It was allowed to be cooled at ambient temperature. The biscuits were packed in aluminium lined pouches and stored at ambient temperature. Surimi powder was added at 10%, 20% and 30% by replacing maida to prepare surimi chocolate biscuits.

3.2.3.2 Preparation of bread

Straight dough AACC (American Association of Cereal Chemists) method numbered 10-10 B was followed (Anonymous, 1990). The formula for control was as follows:

Ingredients : Quantity (g)

Maida : 100

Compressed : 3.0
yeast

Sugar : 2.5

Shortening : 4.0

Salt/NaCl : 1.5

Water : 60 ml

The dough was prepared and baking schedule was followed as below

Mixing : Optimum (3 min)

Fermentation : 75 min (1.15 h)

Remixing : 25 sec

Recovery : 20 min

Proofing (at 30°C, :
55 min
RH 75%)

Baking : 25 min at 232°C

Surimi powder was added at 5%, 10% and 15% by replacing maida to

prepare surimi powder incorporated bread. Bread was packed in polyethylene bags and stored at ambient temperature.

3.2.3.3 Preparation of cake

Refined sun flower oil (50ml) was creamed with sugar (100 g) using hand mixer for 8 min. Rest of the ingredients including egg (2no.), maida (100 g) and cocoa powder (10 g) are added and mixed for 2min under constant mixing and was poured in to paper cups. All the cakes were baked for same time and temperature in an baking oven at 180°C for 15 to 20 min. Surimi powder was added at 10%, 20% and 30% by replacing maida to prepare surimi powder incorporated cake. Cakes were packed in polyethylene bags and were stored at ambient temperature.

3.2.4 Analyses of functional properties

3.2.4.1 Analysis of foaming capacity and stability

The method of Miller and Goninger (1976) was used to determine the foaming properties of surimi powder in triplicate. The sample (1 g) was added to 100 ml distilled water in a 250 ml calibrated beaker and homogenized for 1 min at high speed homogenizer. The foaming capacity was calculated as the volume of mixture after blending compared to the original volume. The foaming stability was the ratio of the foaming capacity after 30 min, divided by the initial foaming capacity.

3.2.4.2 Analysis of emulsion capacity and stability

Emulsifying capacity and stability of surimi powder were measured in triplicates following the method of Yatsumatsu et al. (1972). The emulsion (1.0 g surimi powder, 10 ml, distilled water and 10 ml corn oil) was mixed in calibrated centrifuged tube. The emulsion was centrifuged at 2000g for 5 min. The ratio of the

height of emulsion layer to the total height of the mixture was calculated as emulsion capacity in percentage. The emulsion stability was estimated after heating the emulsion contained in calibrated centrifuge tube at 80°C for 30 min in a water-bath, cooled for 15 min under running tap water and centrifuged at 2000g for 15 min. The emulsion stability expressed as percentage was calculated as the ratio of the height of emulsified layer to the total height of the mixture.

3.2.5 Proximate composition analyses of surimi and Bakery products

3.2.5.1 Moisture

Moisture content (%) of surimi powder and bakery products was determined by the standard AOAC method (1995).

3.2.5.2 Crude protein

The nitrogen content of surimi powder and bakery products was determined by the micro kjeldahl method AOAC, (1995) using KEL- PLUS digestion and distillation apparatus and the protein content (%) in wet basis was calculated by multiplying nitrogen content with a factor 6.25.

3.2.5.3 Crude fat

Crude fat content (%) in wet basis of surimi powder and bakery products was determined by soxhelt method (AOAC, 1995) using petroleum ether 60-80°C as solvent in a SOCS PLUS-SCS 4 system.

3.2.5.4 Ash

Ash content (%) in wet basis of surimi powder and bakery products was determined according to standard method (AOAC, 1995).

3.2.5.5 Minerals

Minerals like calcium, phosphorus, iron and zinc of bakery products were analyzed using flame photometer.

Carbohydrates content was calculated by difference method.

3.2.6 Analysis of structural changes of bakery products by SEM (Scanning electron microscopy).

Scanning electron microscope was used to view bakery products in three dimensions and to determine the microstructure of the products. The bakery product sample was mounted on SEM stub using double sided adhesive tape and was coated with platinum. An accelerating potential of 5KV was used during micrography.

3.2.7 Analysis of functional changes of bakery products by FTIR

Sample was placed on to the crystal cell and the cell was clamped in to the mount of FTIR Spectrometer. The signal was collected from range of 400-4000 cm^{-1} in 32 scans at a resolution of 4 cm^{-1} and was ratioed against a background spectrum recorded from the clean empty cell at 25°C.

3.2.8 Examination of shelf stability of bakery products by estimation of indices of rancidity

3.2.8.1 Estimation of Thiobarbituric acid Reactive Substances (TBARS)

Thiobarbituric Acid Reactive Substances (TBARS) as an indicator for lipid oxidation of surimi powder and bakery products were analyzed by the method of Zeb and Ullah (2016).

3.2.8.2 Estimation of Peroxide Value (PV) by titrimetric method

Peroxide values of the surimi and bakery products samples were determined

according to Jacobs (1958). Sample (10 g) was homogenized with 15g of anhydrous sodium sulphate to remove moisture using pestle and mortar. The fat was extracted with 50 ml of chloroform and the filtrate was obtained. A total of 15 ml of the chloroform filtrate was mixed with 15ml of glacial acetic acid and 10 ml of 10% potassium iodide solution. It was then kept in a dark place for 10 min and 50 ml of distilled water was added and the liberated iodine was titrated with 0.02 N sodium thiosulfate in the presence of 1 ml of freshly prepared 1% starch solution until the disappearance of the blue colour. PV was calculated and expressed as milli equivalent O₂/Kg of fat.

$$\text{Peroxide value (m.eq.O}_2\text{/Kg)} = \frac{1000 \times (V-X) \times N \times \text{volume of extract}}{W \times \text{aliquot sample vol.}} \rightarrow \text{Equation-2}$$

where, W is the Weight of sample, V is the Vol. of 0.02N sodium thiosulphate used for sample (ml), X is the Vol. of 0.02N sodium thiosulphate used for blank (ml) and N is the Normality of sodium thiosulphate solution.

3.2.8.3 Estimation of Free fatty acid (FFA)

Free fatty acid in the surimi powder and bakery products during storage was estimated as per the method of Ke et al. (1976). 10 g of the sample was grinded with 15 g sodium sulphate and 30 ml chloroform was added and the contents were mixed well. After 10 -15 min, it was filtered to get a chloroform extract of fat. From that 10 ml of extract was taken and 3 drops of 0.5% meta cresol purple was added as an indicator. The FFA extract was titrated till the purple coloured end point was reached using 0.05 N aqueous sodium hydroxide solution. The amount of free fatty acid was calculated using the formula

$$\text{FFA (\%)} = (T - B) \times N \times 2.82 / S \quad \longrightarrow \quad \text{Equation-3}$$

Where, S is the weight of the sample; N is the normality of sodium hydroxide, T is the titre value, B is the blank value.

3.2.9 Sensory evaluation of bakery products

Sensory evaluation of the bakery products were carried out by a panel of 30 subject experts available in the Fisheries College and Research Institute, Thoothukudi. They were asked to indicate their opinion on a 9 point hedonic scale. The experts analysed each bakery product for their appearance, colour, odour, mouth feel, flavour, texture, taste, and overall acceptability of the product. The scale of likeness used for the study was; 1 Dislike extremely; 2 Dislike very much; 3 Dislike moderately; 4 Dislike slightly; 5 Neither like nor dislike; 6 Like slightly; 7 Like moderately; 8 Like very much; and 9 Like extremely.

3.2.10 Analysis of microbial quality

For the enumeration of bacteria, 25 g of surimi and bakery products, sample was taken aseptically and homogenized with 225 ml of sterile saline (0.85% NaCl). Then, the homogenized sample was serially diluted using 9 ml diluents prior to plating. From each dilution, inoculum was taken for enumerating total plate count and total fungal count. The media, methodology, incubation period and time adopted for the enumeration of microbes are given in Table3.1

Table 3.1. Media, methodology, incubation period and time adopted for the enumeration of microbes

S.NO	Target microbe	Media/ Broth	Method	Incubation	Reference
1	Total plate count (TPC)	Plate count Agar	Spread plate	48 h at 37°C	APHA, 1976
2	Total fungal count (TFC)	Potato dextrose agar	Spread plate	48 h at 37°C	APHA,1976

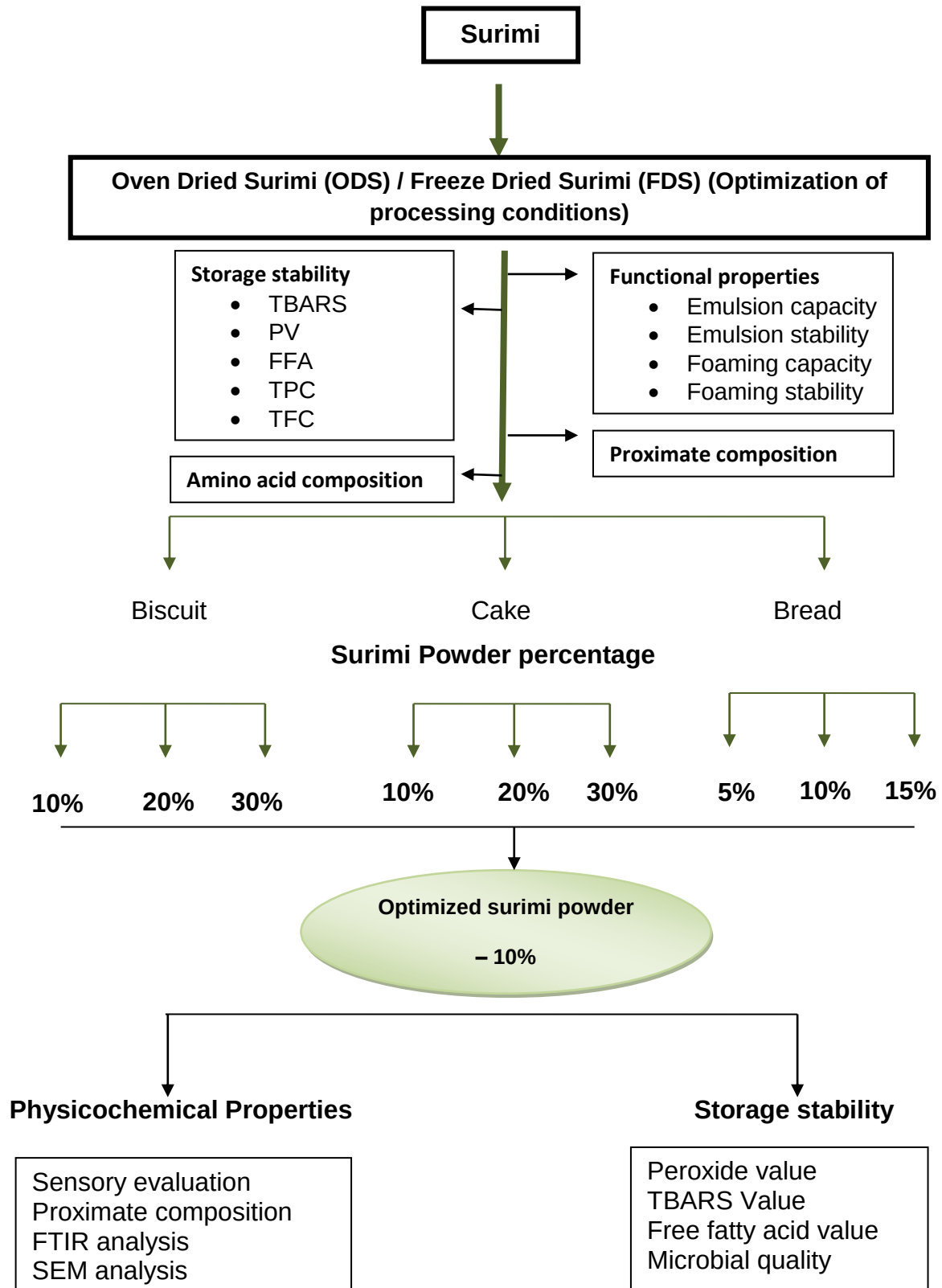
3.2.11. Amino acid composition

Amino acid composition of the bakery products were analysed using the facilities at Agricultural College and Research Institute, TNAU campus, Madurai, using H Class-Ultra Performance Liquid Chromatography (UHPLC) following the method prescribed by Waters (India) Pvt. Ltd. Bangalore.

3.3 Statistical analysis

The analysis of triplicate results was performed using tools from SPSS 22. The results were expressed as mean $\pm$ standard deviation (SD). ANOVA and Paired T test were performed to evaluate the significance level among the experimental groups.

Experimental design



IV. RESULTS

Itoyori surimi was purchased from Gadre Marine Pvt. Ltd, Brahmavar and was dried using two different methods *viz.* freeze drying and oven drying, for which the conditions were optimized and both types of dried surimi were powdered. The proximate composition and functional properties *viz.* emulsion capacity, emulsion stability, foaming capacity and foaming stability of both types of surimi powder were examined along with shelf stability characteristics *viz.* TBARS value, peroxide value, free fatty acid and microbial quality characteristics *viz.* total plate count and total fungal count. Bakery products *viz.* biscuit, cake and bread were formulated using surimi powder for which the proportions of surimi powder were optimized. The nutritional and quality characteristics of the bakery products, such as proximate composition, biochemical, microbiological and sensory characteristics along with structural characteristic using scanning electron microscopy and functional characteristic using Fourier transform infrared spectroscopy were evaluated. The results obtained are presented in this section.

4.1 Surimi powder

4.1.1 Conditions for the preparation of surimi powder

Surimi was dried at different temperatures, *viz.* $45 \pm 5^{\circ}\text{C}$, $50 \pm 5^{\circ}\text{C}$, $55 \pm 5^{\circ}\text{C}$ and 60°C . Since the dried product started to show discolouration (brown) and charring at $60 \pm 5^{\circ}\text{C}$, the optimum temperature for oven drying surimi was determined as $55 \pm 5^{\circ}\text{C}$. The condenser temperature, freezing temperature and pressure for freeze drying were -50°C , -23°C and 0.5mbar, respectively. As these

operating conditions were equipment specific, the time for freeze drying was the variable optimized. The time for freeze drying was optimized as 8 h, as the moisture drop after this time was negligible.

4.1.2 Functional properties of surimi powder

The functional properties viz. emulsion capacity, emulsion stability, foaming capacity and foaming stability of the freeze dried surimi (FDS) powder and oven dried surimi (ODS) powder were examined and the results as mean of triplicates are given in Table 4.1.

Table 4.1. Functional properties of surimi powder

Surimi powder	Emulsion Capacity (%)	Emulsion Stability (%)	Foaming Capacity (%)	Foaming Stability (%)
FDS	70.67 ± 1.15	54.67 ± 1.15	48.67 ± 1.15	5.13 ± 0.12
ODS	68.67 ± 1.15	51.33 ± 0.58	45.33 ± 0.58	4.2 ± 0.00

Emulsion capacity, emulsion stability, foaming capacity and foaming stability of FDS powder were 70.67 ± 1.15%, 54.67 ± 1.15%, 48.67 ± 1.15% and 5.13 ± 0.12%, respectively whereas that of oven dried surimi (ODS) powder were 68.67 ± 1.15%, 51.33 ± 0.58%, 45.33 ± 0.58% and 4.2 ± 0.00%, respectively.

4.1.3 Proximate composition of surimi powder

The proximate composition of the freeze dried surimi (FDS) powder and oven dried surimi (ODS) powder were examined and the results are given in Fig. 4.1.

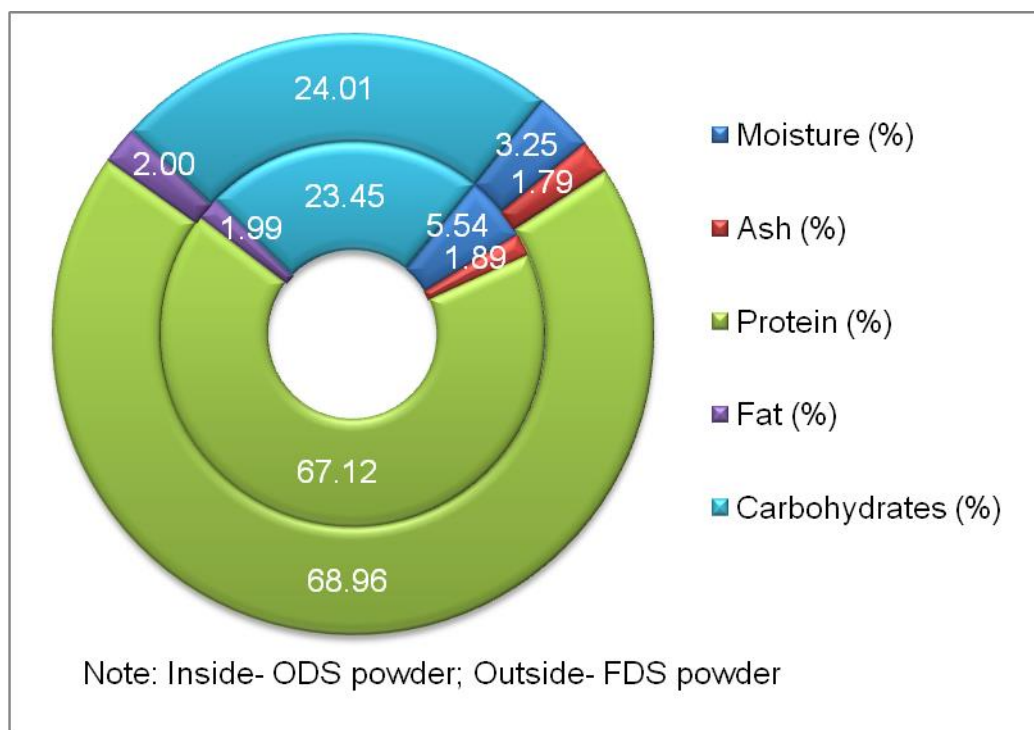


Fig. 4.1. Proximate composition ODS and FDS powder

The moisture, ash, protein, fat and carbohydrates contents of FDS powder were $3.25 \pm 0.30\%$, $1.79 \pm 0.10\%$, $68.96 \pm 0.18\%$, $2.00 \pm 0.07\%$ and $24.01 \pm 0.42\%$, respectively while that of ODS powder were $5.54 \pm 0.26\%$, $1.89 \pm 0.17\%$, $67.12 \pm 0.42\%$, $1.99 \pm 0.12\%$ and $23.45 \pm 0.91\%$, respectively.

4.1.4 Storage stability of surimi powder

4.1.4.1 TBARS value of surimi powder during storage

The TBARS values of FDS and ODS powder during storage were estimated and the results are given in Fig. 4.2.

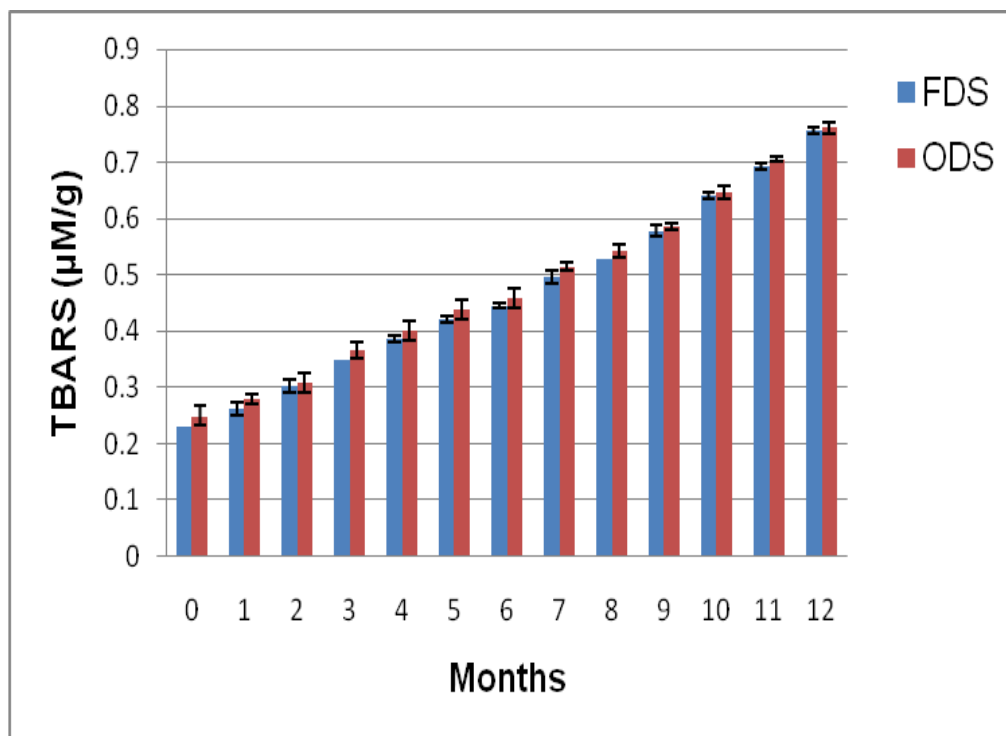


Fig. 4.2. TBARS value of surimi powder during storage

The TBARS values of FDS and ODS powder on the 0th month were 0.23 μM/g and 0.25μM/g, respectively which gradually increased to 0.76 μM/g in both FDS and ODS by the end of the 12th month.

4.1.4.2 Peroxide value of surimi powder during storage

Peroxide value (PV) of FDS and ODS powder during storage were estimated and the results are given in Fig. 4.3.

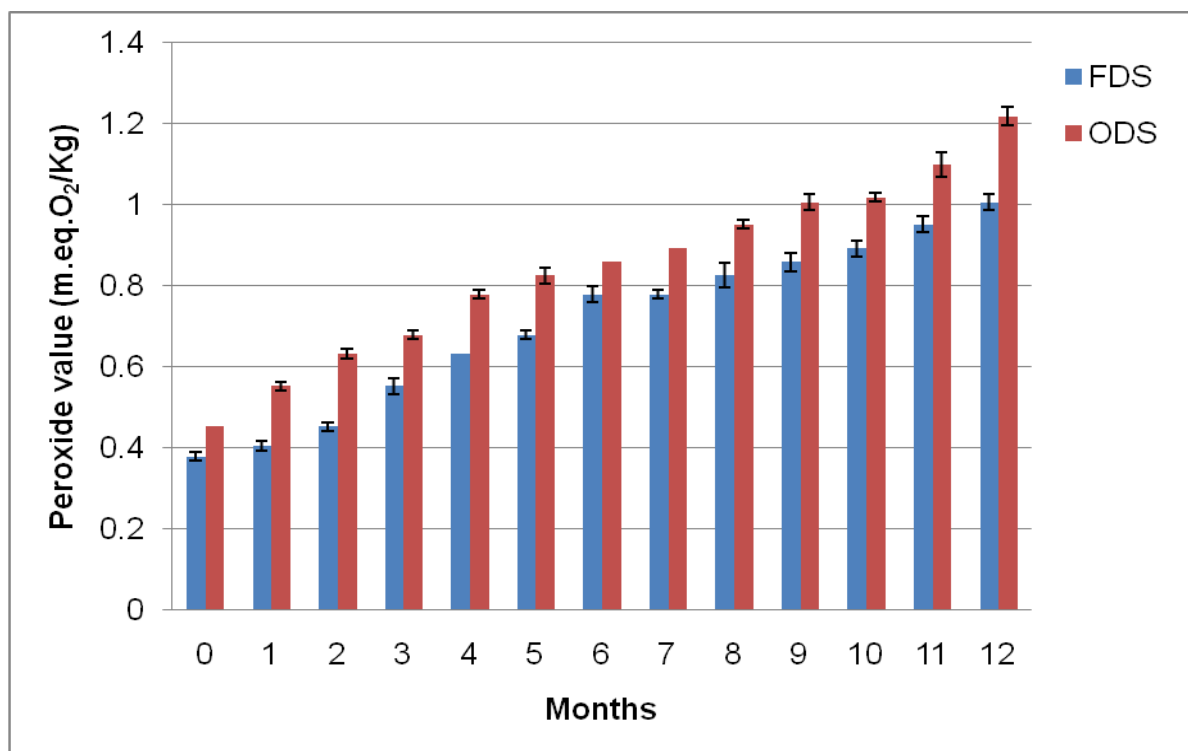


Fig. 4.3. Peroxide value of surimi powder during storage

The peroxide value of FDS and ODS powder were 0.38 m.eq.O₂/Kg and 0.45 m.eq.O₂/Kg, respectively on the 0th month, which increased to 1.01 m.eq.O₂/Kg and 1.22 m.eq.O₂/Kg in FDS and ODS, respectively by the end of the 12th month.

4.1.4.3 Free fatty acid in surimi powder during storage

Free fatty acid in FDS and ODS powder during storage were estimated and the results are given in Fig. 4.4.

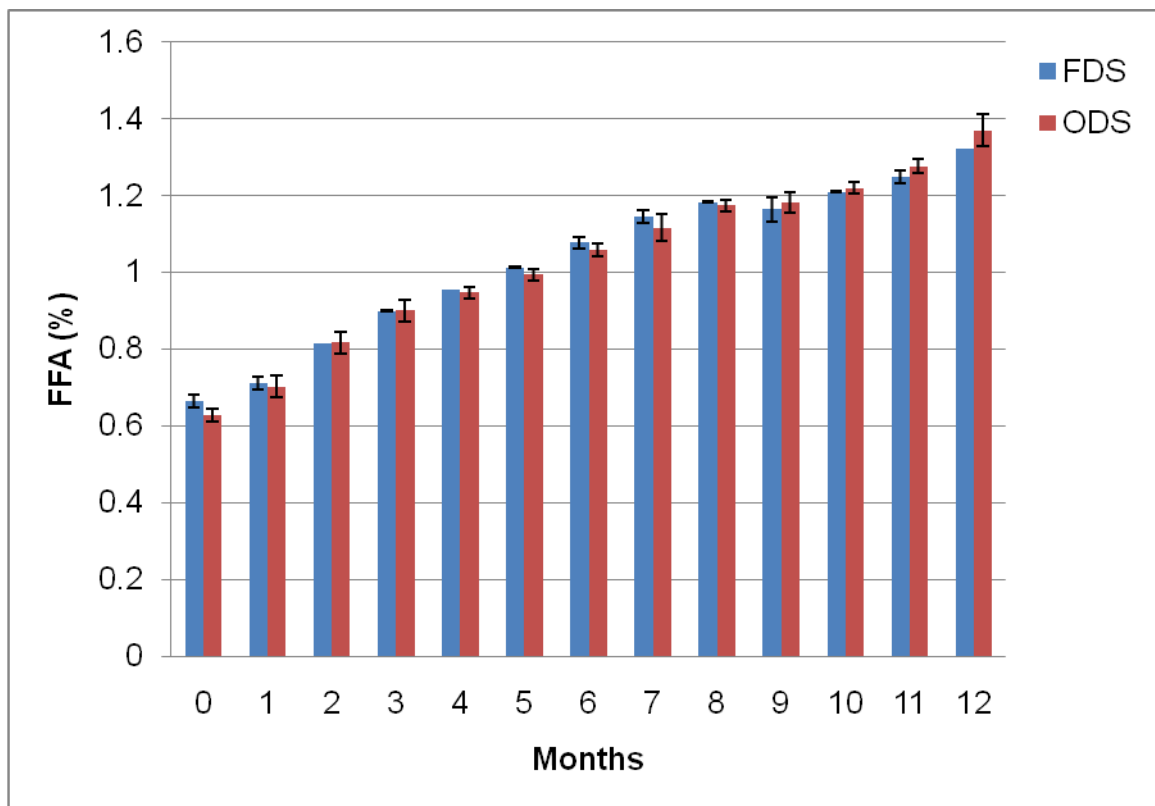


Fig. 4.4. Free fatty acid in surimi powder during storage

Free fatty acid in FDS and ODS powder increased from 0.67% and 0.63%, respectively on the 0th month to 1.32% and 1.37% by the end of the 12th month, respectively.

4.1.5 Microbial quality of surimi powder during storage

The total plate count of FDS and ODS powder were estimated and the results are given in Fig. 4.5.

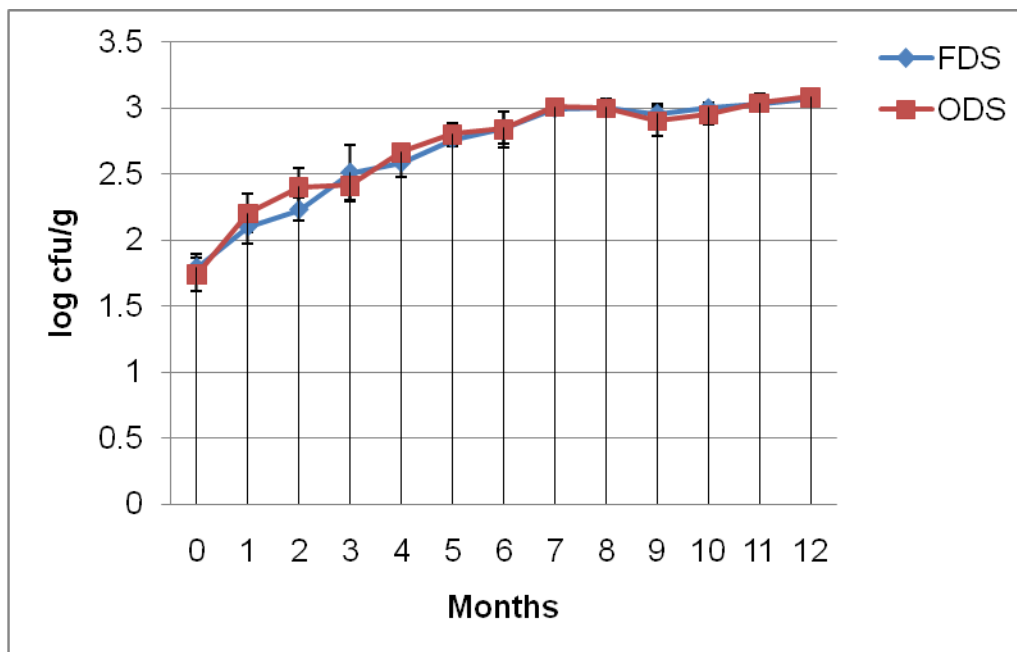


Fig. 4.5. Total plate count of surimi powder during storage

The total plate count of FDS and ODS powder were 1.79 ± 0.10 logcfu/g and 1.74 ± 0.13 logcfu/g on the 0th day, which gradually increased to 3.08 ± 0.06 logcfu/g and 3.09 ± 0.06 logcfu/g, respectively by the end of the 12th month. Total fungal count was not detected in both the types of surimi powder.

4.2 Biscuit

Biscuit were prepared by incorporating different proportions of FDS and ODS powder and their different characteristics were evaluated.

4.2.1 Proximate composition of biscuit incorporated with surimi powder

The proximate composition of biscuit incorporated with FDS powder and that incorporated with ODS powder was estimated and the results are given in Fig. 4.6. and Fig. 4.7., respectively.

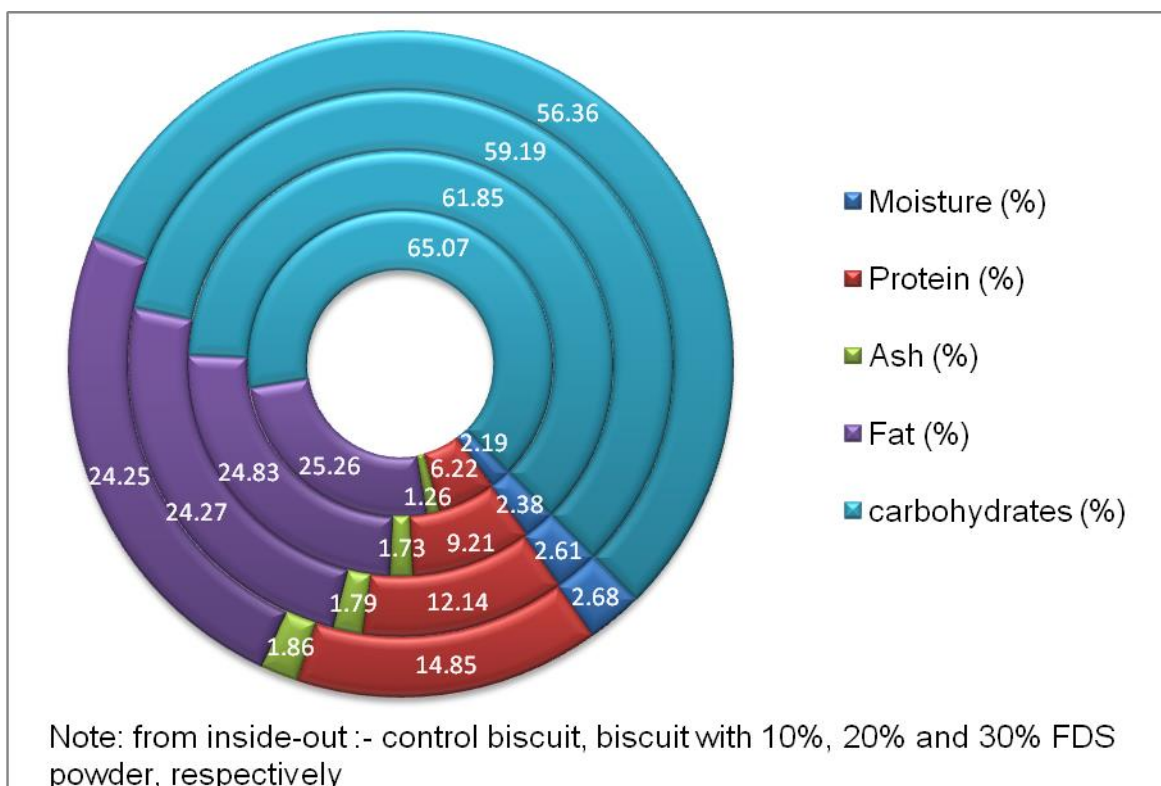


Fig. 4.6. Proximate composition of biscuit incorporated with FDS powder

The moisture, ash, fat, protein and carbohydrates contents in control biscuit, biscuit incorporated with 10% FDS, biscuit incorporated with 20% FDS and biscuit with 30% FDS were $2.19 \pm 0.09\%$, $1.26 \pm 0.05\%$, $25.26 \pm 0.23\%$, $6.22 \pm 0.09\%$ and $65.07 \pm 0.27\%$, respectively, $2.38 \pm 0.06\%$, $1.73 \pm 0.06\%$, $24.83 \pm 0.04\%$, $9.21 \pm 0.11\%$ and $61.85 \pm 0.15\%$, respectively, $2.61 \pm 0.21\%$, $1.79 \pm 0.10\%$, $24.27 \pm 0.08\%$, $12.14 \pm 0.17\%$ and $59.19 \pm 0.22\%$, respectively and $2.68 \pm 0.15\%$, $1.86 \pm 0.05\%$, $24.25 \pm 0.21\%$, $14.85 \pm 0.21\%$ and $56.36 \pm 0.02\%$, respectively.

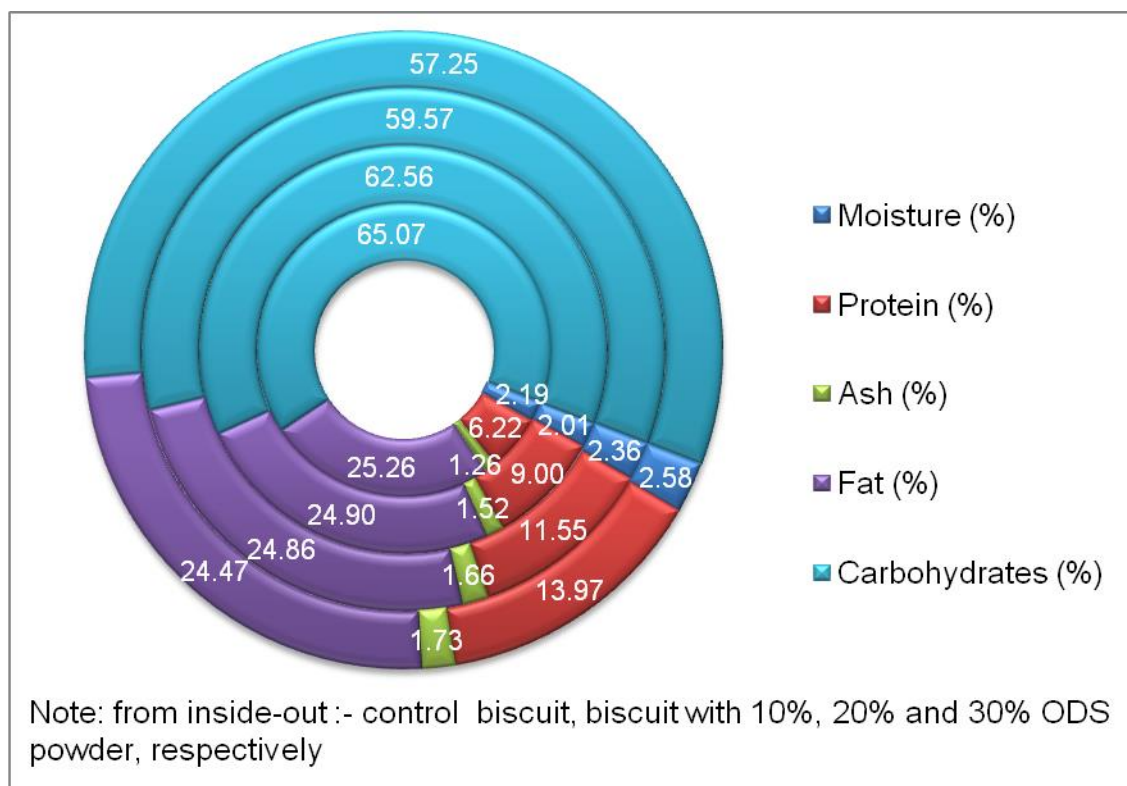


Fig. 4.7. Proximate composition of biscuit incorporated with ODS powder

The moisture, ash, fat, protein and carbohydrates contents in control biscuit, biscuit incorporated with 10% ODS, biscuit incorporated with 20% ODS and biscuit with 30% ODS were $2.19 \pm 0.09\%$, $1.26 \pm 0.05\%$, $25.26 \pm 0.23\%$, $6.22 \pm 0.09\%$ and $65.07 \pm 0.27\%$, respectively, $2.01 \pm 0.08\%$, $1.52 \pm 0.06\%$, $24.90 \pm 0.03\%$, $9.00 \pm 0.09\%$ and $62.56 \pm 0.08\%$, respectively, $2.36 \pm 0.16\%$, $1.66 \pm 0.06\%$, $24.86 \pm 0.20\%$, $11.55 \pm 0.15\%$ and $59.57 \pm 0.27\%$, respectively and $2.58 \pm 0.10\%$, $1.73 \pm 0.05\%$, $24.47 \pm 0.18\%$, $13.97 \pm 0.23\%$ and $57.25 \pm 0.33\%$, respectively.

Plate I. Biscuits incorporated with surimi powder



Control biscuit



FDS biscuit



ODS biscuit

4.2.2 Sensory evaluation of biscuit incorporated with surimi powder

The sensory evaluation of biscuit incorporated with FDS powder and that incorporated with ODS powder were estimated and the results are given in Fig. 4.8. and Fig. 4.9., respectively.

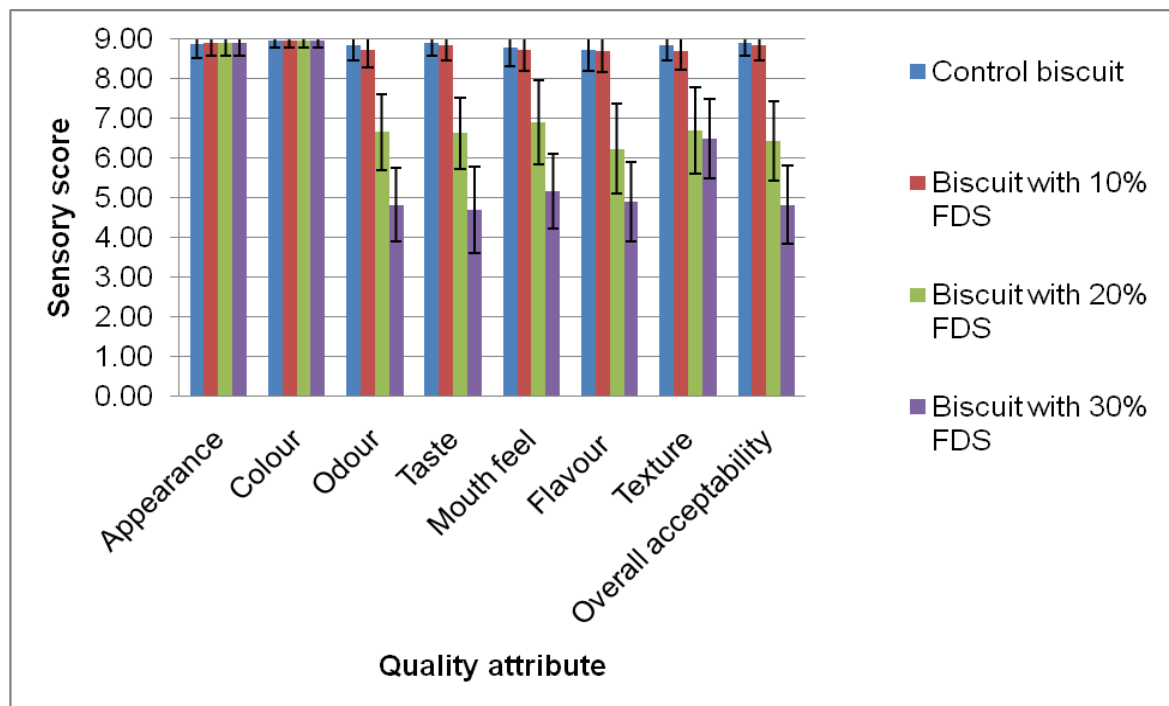


Fig. 4.8. Sensory scores of biscuit incorporated with FDS powder

The average sensory scores for control biscuit, biscuits incorporated with 10%, 20% and 30% FDS powder were 8.90 ± 0.31 , 8.90 ± 0.31 , 8.90 ± 0.31 and 8.90 ± 0.31 , respectively for the appearance, 8.97 ± 0.18 , 8.97 ± 0.18 , 8.97 ± 0.18 and 8.97 ± 0.18 , respectively for the colour, 8.83 ± 0.38 , 8.73 ± 0.45 , 6.67 ± 0.96 , 4.83 ± 0.91 , respectively for the odour, 8.90 ± 0.31 , 8.83 ± 0.38 , 6.63 ± 0.89 and 4.70 ± 1.09 , respectively for the taste, 8.80 ± 0.48 , 8.73 ± 0.52 , 6.90 ± 1.06 and 5.17 ± 0.95 , respectively for the mouth feel, 8.73 ± 0.52 , 8.70 ± 0.53 , 6.23 ± 1.14

and 4.90 ± 0.99 , respectively for the flavour, 8.83 ± 0.38 , 8.70 ± 0.47 , 6.70 ± 1.09 and 6.50 ± 1.01 , respectively for the texture and 8.90 ± 0.31 , 8.83 ± 0.38 , 6.43 ± 1.01 and 4.83 ± 0.99 , respectively for overall acceptability.

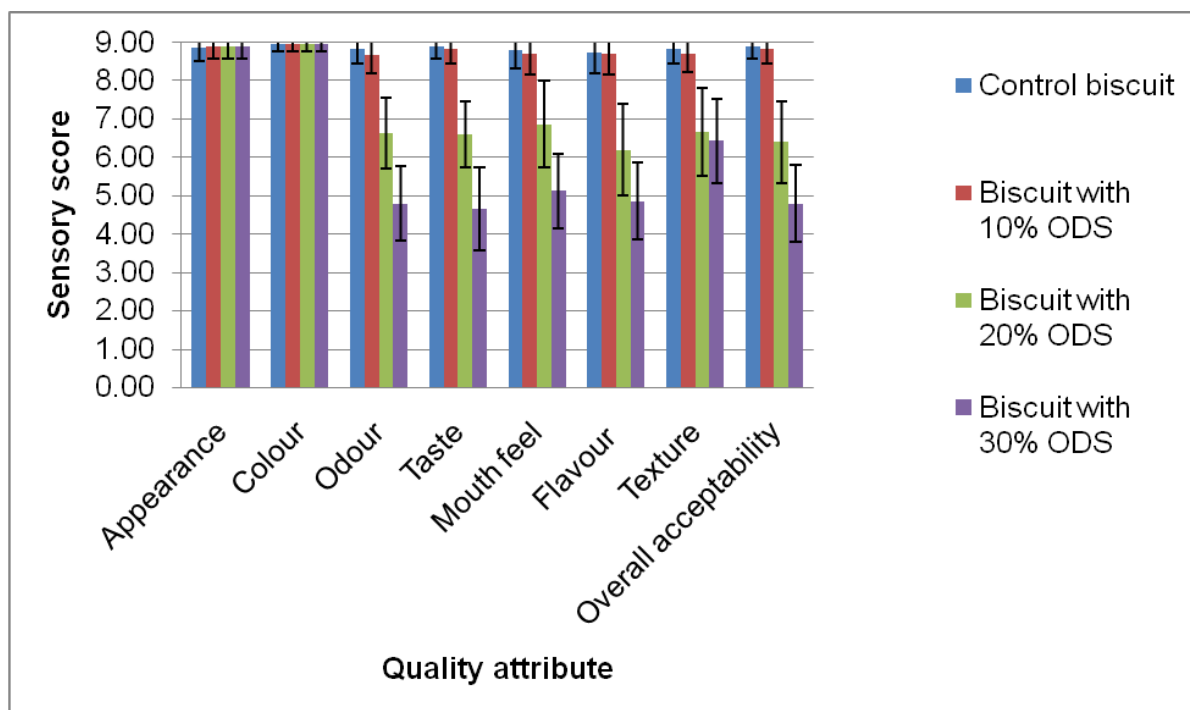


Fig. 4.9. Sensory evaluation of biscuit incorporated with ODS powder

The sensory scores on an average for control biscuit, biscuits incorporated with 10%, 20% and 30% ODS powder were 8.90 ± 0.31 , 8.90 ± 0.31 , 8.90 ± 0.31 and 8.90 ± 0.31 , respectively for the appearance, 8.97 ± 0.18 , 8.97 ± 0.18 , 8.97 ± 0.18 and 8.97 ± 0.18 , respectively for the colour, 8.83 ± 0.38 , 8.67 ± 0.48 , 6.63 ± 0.93 and 4.80 ± 0.96 , respectively for the odour, 8.90 ± 0.31 , 8.83 ± 0.38 , 6.60 ± 0.86 and 4.67 ± 1.09 , respectively for the taste, 8.80 ± 0.48 , 8.70 ± 0.53 , 6.87 ± 1.14 and 5.13 ± 0.97 , respectively for the mouth feel, 8.73 ± 0.52 , 8.70 ± 0.53 , 6.20 ± 1.19 and 4.87 ± 1.01 , respectively for the flavour, 8.83 ± 0.38 , 8.70 ± 0.47 , 6.67 ± 1.19 and 4.87 ± 1.01 , respectively for the texture and 8.90 ± 0.31 , 8.83 ± 0.38 , 6.43 ± 1.01 and 4.83 ± 0.99 , respectively for overall acceptability.

1.15 and 6.43 ± 1.10 , respectively for the texture and 8.90 ± 0.31 , 8.83 ± 0.38 , 6.40 ± 1.07 and 4.80 ± 1.00 , respectively for overall acceptability.

4.2.3 Microstructure of biscuits

Scanning electron microscopic images of control biscuit, biscuits incorporated with 10% FDS powder and that incorporated with 10% ODS powder were observed and the images are given in Fig. 4.10, Fig. 4.11 and Fig. 4.12, respectively.

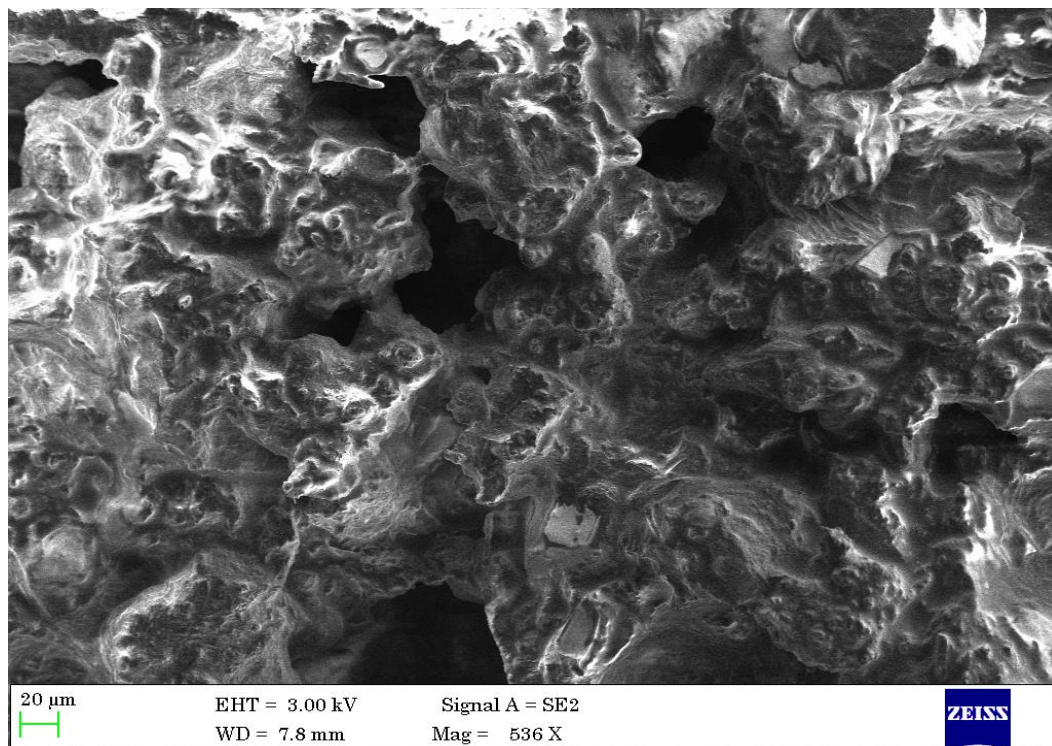


Fig. 4.10 SEM image of control biscuit

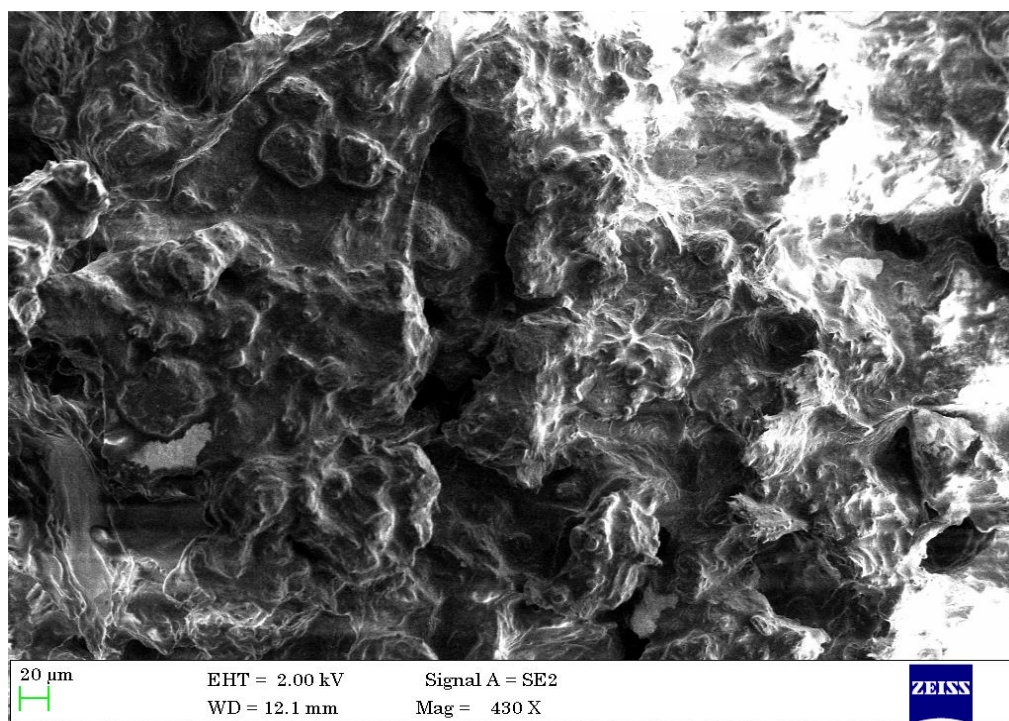


Fig. 4.11 SEM image of FDS biscuit

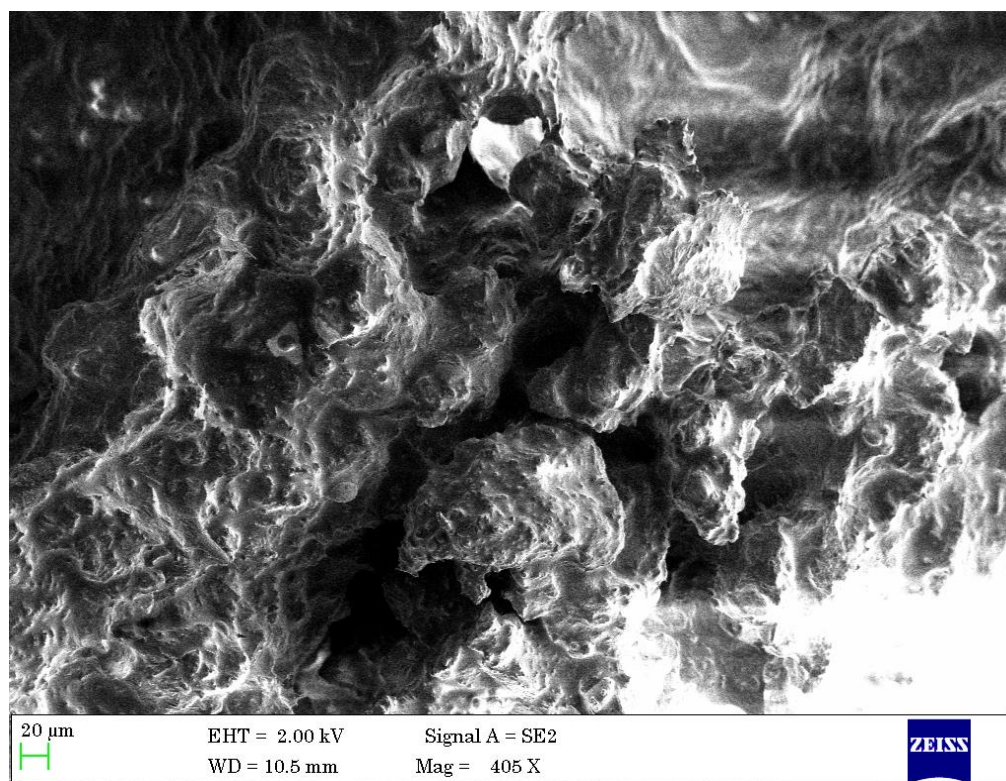


Fig. 4.12 SEM image of ODS biscuit

A layer of lipid molecules was visible in all the products. Greater uniformity and high compaction of the product were observed in control biscuit. There was no difference observed between control and surimi added products.

4.2.4 Storage stability of biscuits incorporated with surimi powder

Storage stability of biscuits incorporated with surimi powder were analyzed by estimating their TBARS value, peroxide value, free fatty acid value and microbial quality during their storage.

4.2.4.1 TBARS value of biscuits incorporated with surimi powder during storage

The TBARS values of biscuits incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.13.

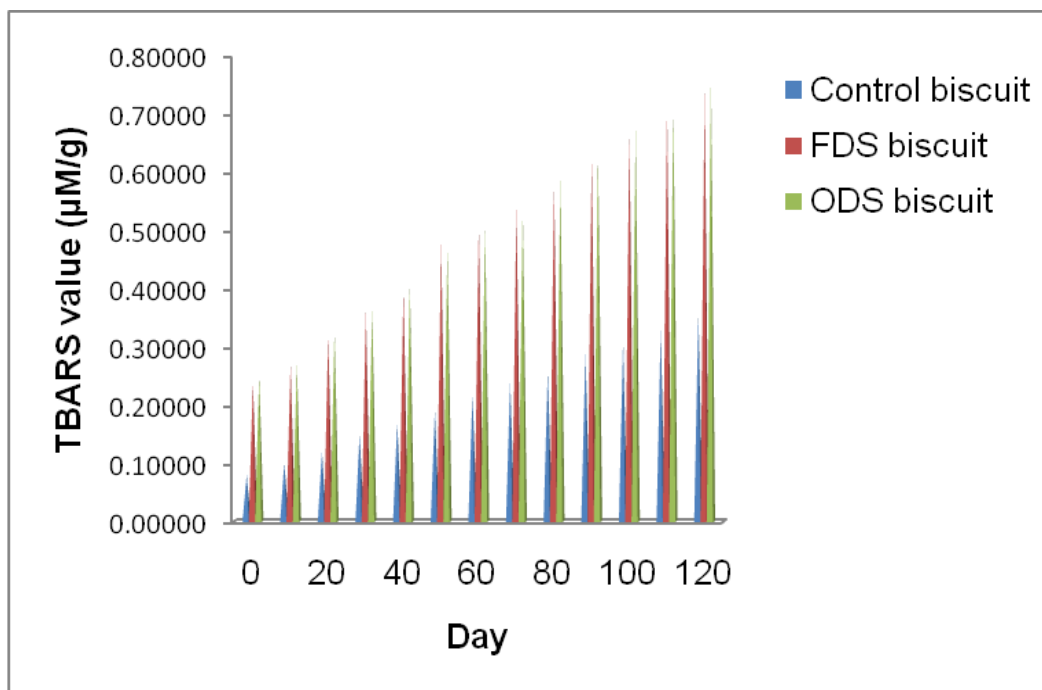


Fig. 4.13. TBARS value of biscuits during storage

The TBARS values of control biscuit, biscuit incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.08 $\mu\text{M/g}$, 0.24 $\mu\text{M/g}$ and 0.25 $\mu\text{M/g}$, respectively, which gradually increased to 0.36 $\mu\text{M/g}$, 0.74 $\mu\text{M/g}$ and 0.76 $\mu\text{M/g}$, respectively by the end of the 120th day.

4.2.4.2 Peroxide value of biscuits incorporated with surimi powder during storage

The peroxide values of biscuits incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.14.

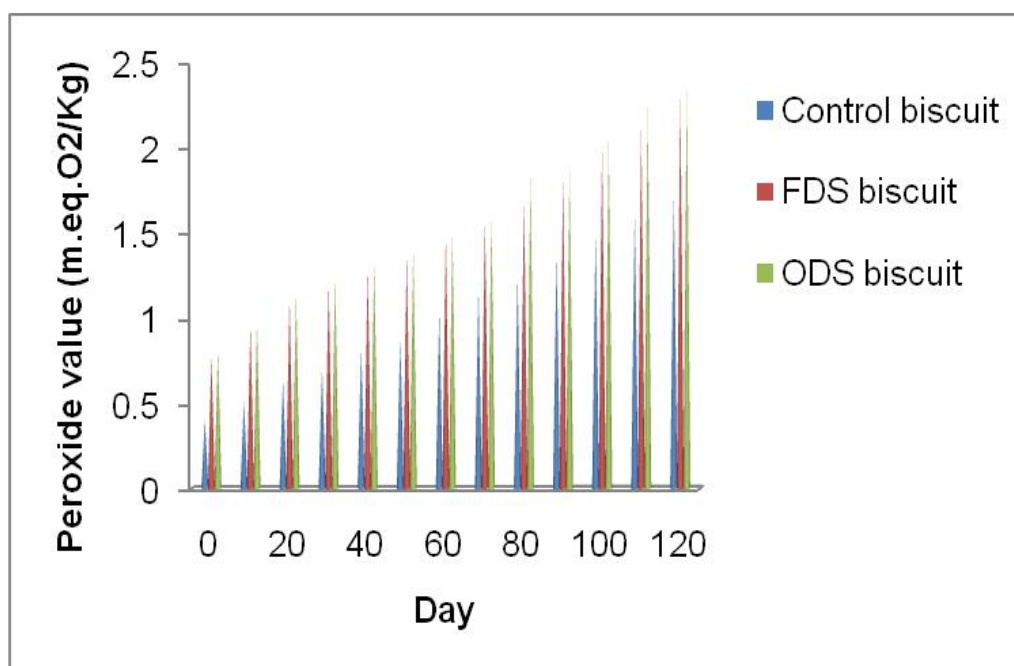


Fig. 4.14. Peroxide value of biscuits during storage

The peroxide values of control biscuit, biscuit incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.41 ± 0.01 m.eq.O₂/Kg, 0.78 ± 0.00 m.eq.O₂/Kg and 0.81 ± 0.03 m.eq.O₂/Kg, respectively, which gradually

increased to 1.73 ± 0.01 m.eq.O₂/Kg, 2.31 ± 0.01 m.eq.O₂/Kg and 2.34 ± 0.03 m.eq.O₂/Kg, respectively by the end of the 120th day.

4.2.4.3 Free fatty acid in biscuits incorporated with surimi powder during storage

The free fatty acid in biscuits incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.15.

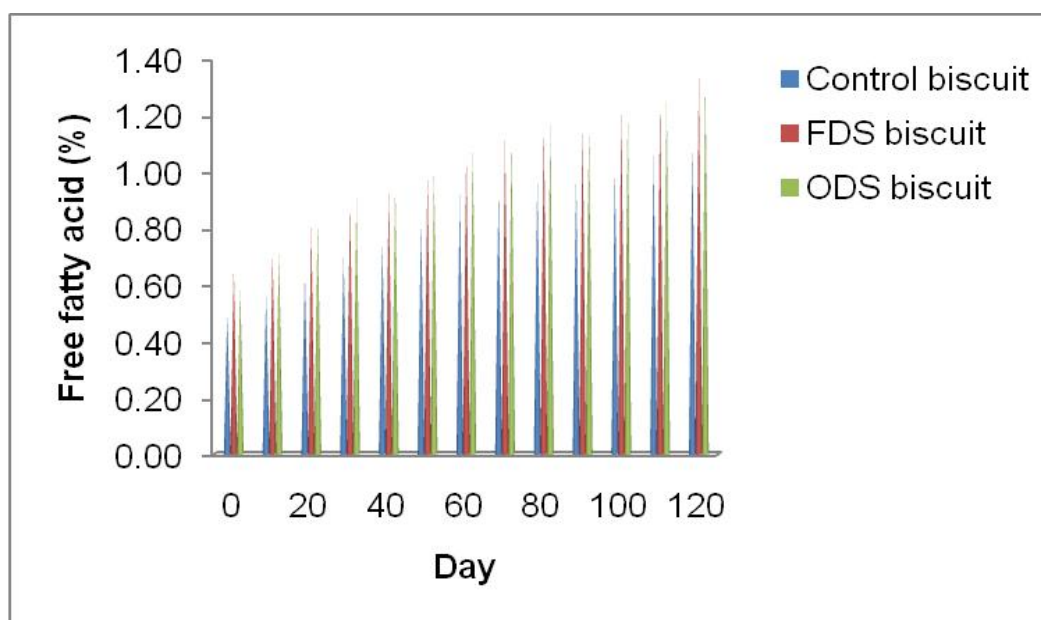


Fig. 4.15. Free fatty acids in biscuits during storage

The free fatty acid in control biscuit, biscuit incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.50 \pm 0.02\%$, $0.66 \pm 0.02\%$ and $0.59 \pm 0.00\%$, respectively, which gradually increased to $1.11 \pm 0.04\%$, $1.34 \pm 0.02\%$ and $1.33 \pm 0.02\%$, respectively by the end of the 120th day.

4.2.5 Microbial quality of biscuits during storage

The total plate count of control biscuits, biscuits incorporated with FDS powder and that incorporated with ODS powder were estimated and the results are given in Fig. 4.16.

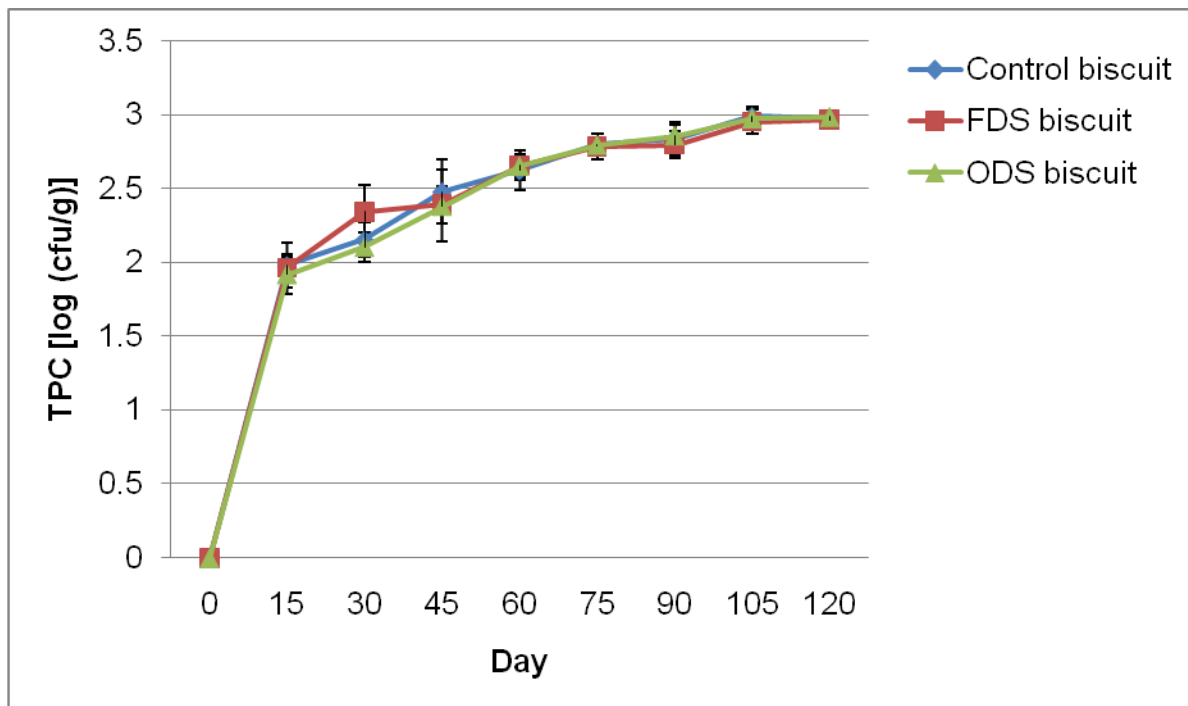


Fig. 4.16. Total plate count of biscuits

The total plate count of control biscuits, biscuits incorporated with FDS powder and that incorporated with ODS powder were not detected on the 0th day and were 1.98 ± 0.15 logcfu/g, 1.97 ± 0.07 logcfu/g and 1.92 ± 0.14 logcfu/g on the 15th day and then gradually increased to 2.97 ± 0.04 logcfu/g, 2.97 ± 0.05 logcfu/g and 2.99 ± 0.03 logcfu/g, respectively on the 120th day. Total fungal count was not detected in any of the biscuits during the entire storage period.

4.2.6 Fourier Transform Infrared Spectroscopy of biscuits

FTIR spectrum was analysed to examine the functional interaction that took place during the formulation and processing of biscuits. The FTIR Spectra were collected in the transmission mode using FTIR Spectrometer for the different ingredients *viz.* cocoa powder, maida, sugar, shortening, FDS powder and ODS powder, and also the final products *viz.* control biscuit, biscuits incorporated with FDS powder and that incorporated with ODS powder and are given in Fig 4.17 to Fig. 4.25 and the peaks are assigned in Table 4.2.

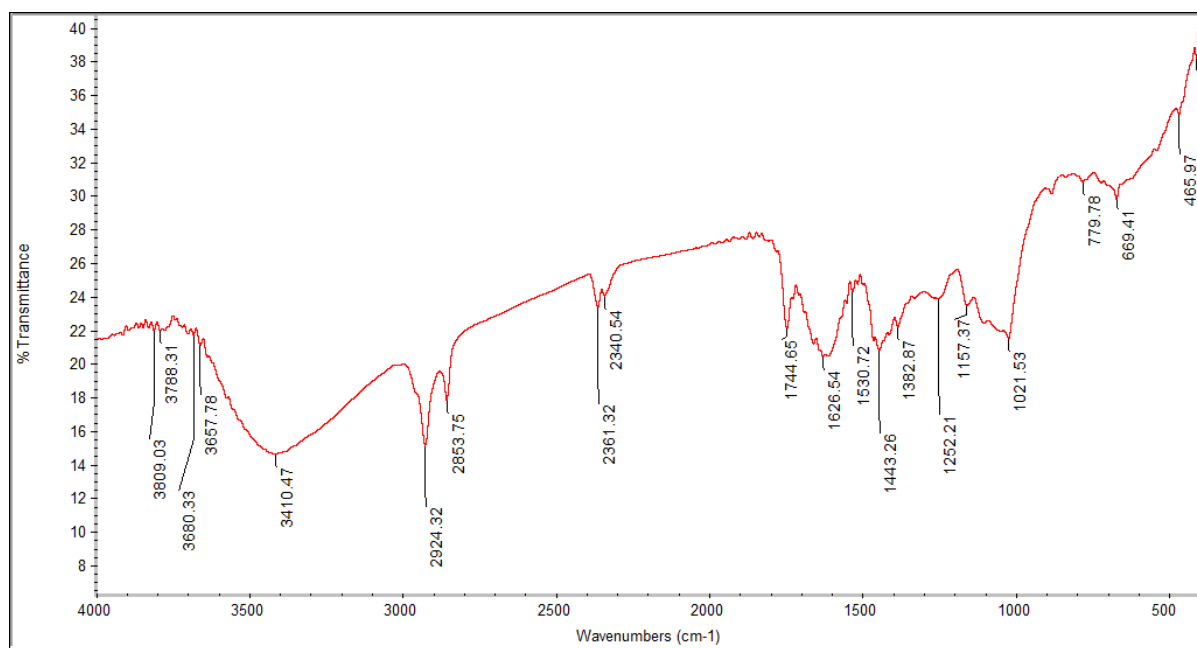


Fig. 4.17. FTIR analysis of cocoa powder

The FTIR peaks at 3410 cm^{-1} , 2924 cm^{-1} , 2853 cm^{-1} , 2361 cm^{-1} , 2341 cm^{-1} , 1745 cm^{-1} , 1531 cm^{-1} , 1443 cm^{-1} , 1383 cm^{-1} , 1252 cm^{-1} , 1157 cm^{-1} , 1022 cm^{-1} , 780 cm^{-1} , 669 cm^{-1} and 466 cm^{-1} were obtained for cocoa powder for which the probable assignments are O-H, C-H/N-H, C-H (symmetric)/N-H, N=H, C-O vibration, C-H

stretching/C=O/Asp-95, N-H, in-plane mode of N-H, C-H bending, C-F Stretch, C-F Stretch /C-O/C-N stretch, C-O, C-H out of plane vibration, C-Br/N-H wag amines and vibrations of PO₄ respectively. The unidentified peaks were obtained at 3809 cm⁻¹, 3788 cm⁻¹, 3680 cm⁻¹ and 3657 cm⁻¹ for cocoa powder.

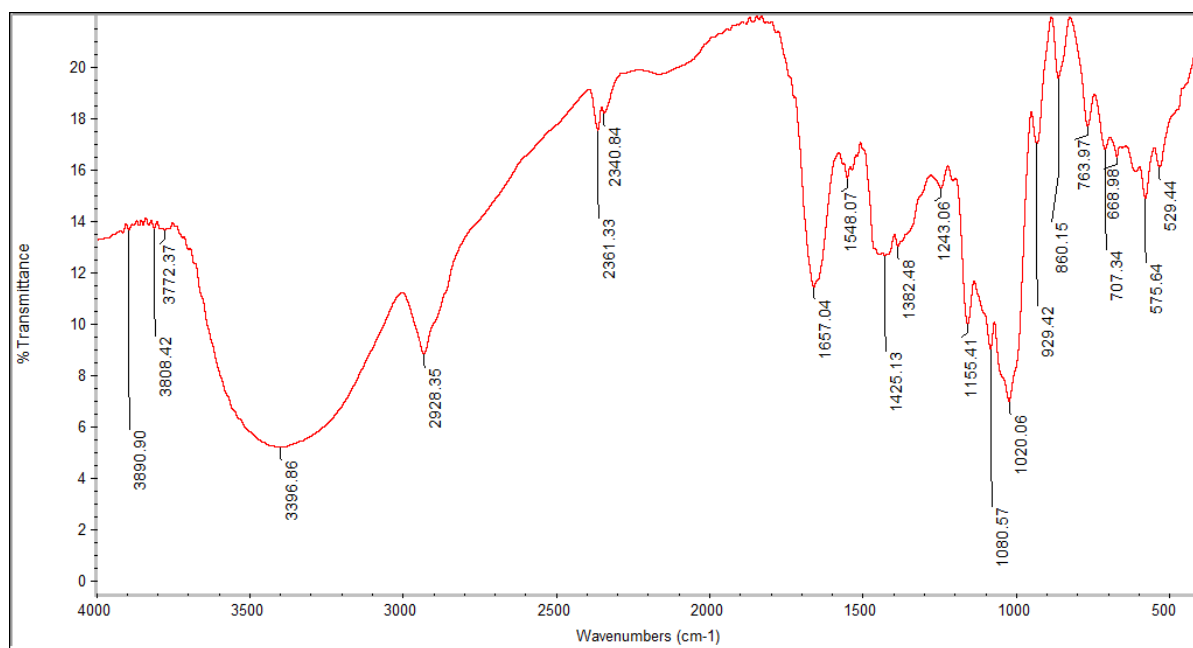


Fig. 4.18. FTIR analysis of Maida

The FTIR peaks at 3397 cm⁻¹, 2928 cm⁻¹, 2361 cm⁻¹, 2341 cm⁻¹, 1657 cm⁻¹, 1548 cm⁻¹, 1425 cm⁻¹, 1382 cm⁻¹, 1243 cm⁻¹, 1155 cm⁻¹, 1081 cm⁻¹, 1020 cm⁻¹, 929 cm⁻¹, 860 cm⁻¹, 764 cm⁻¹, 707 cm⁻¹, 669 cm⁻¹, 576 cm⁻¹ and 529 cm⁻¹ were obtained for maida for which the probable assignments are O-H, C-H/N-H, N=H, C-O vibration, C=C/N-H in plane bend, N-H out of plane, C-O stretching and OH deformation of the carboxyl group, C-H bending, C-O, C-F Stretch /C-O/C-N stretch, P=O stretching/C-F Stretch /C-O/C-N stretch, C-O, CH=CH₂ (CH₂ out-of Plane wag), C-H(bend)/ N-H wag amines, C-C, C-H, C-Br/N-H wag amines, C-I and C-I,

respectively. Unidentified peaks were obtained at 3891 cm^{-1} , 3808 cm^{-1} and 3772 cm^{-1} for maida.

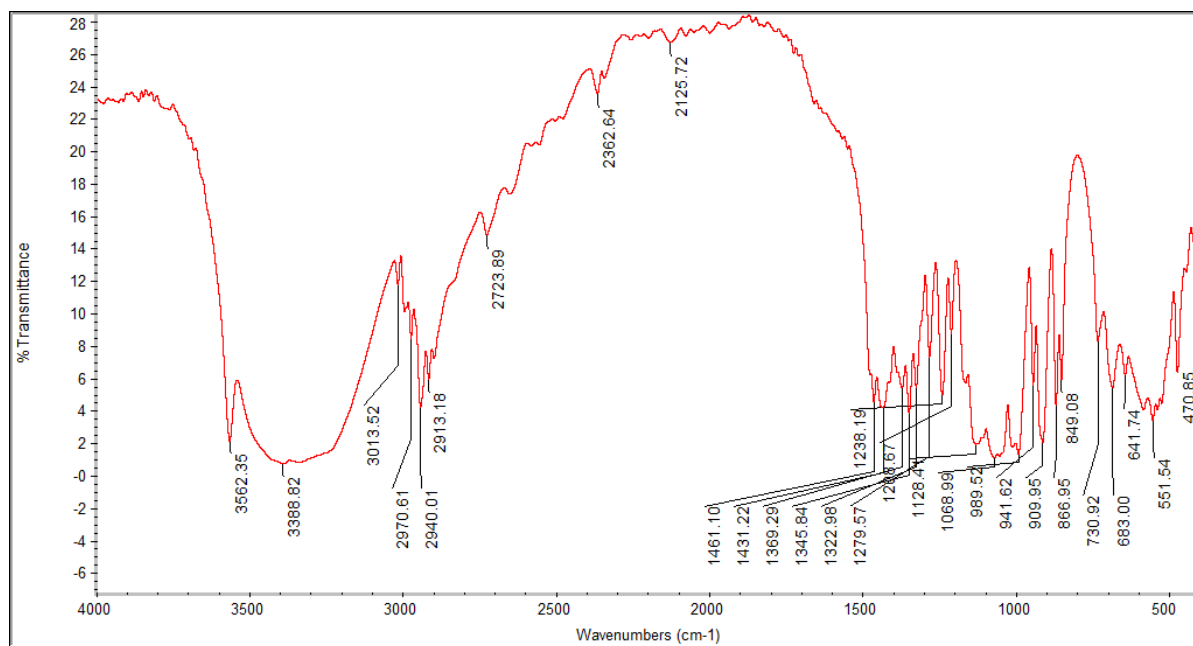


Fig. 4.19. FTIR analysis of Sugar

The FTIR peaks at 3562 cm^{-1} , 3389 cm^{-1} , 3014 cm^{-1} , 2971 cm^{-1} , 2940 cm^{-1} , 2913 cm^{-1} , 2724 cm^{-1} , 2363 cm^{-1} , 2913 cm^{-1} , 2126 cm^{-1} , 1461 cm^{-1} , 1431 cm^{-1} , 1369 cm^{-1} , 1346 cm^{-1} , 1323 cm^{-1} , 1238 cm^{-1} , 1209 cm^{-1} , 1128 cm^{-1} , 1069 cm^{-1} , 990 cm^{-1} , 942 cm^{-1} , 910 cm^{-1} , 867 cm^{-1} , 849 cm^{-1} , 731 cm^{-1} , 683 cm^{-1} , 642 cm^{-1} , 552 cm^{-1} and 471 cm^{-1} were obtained for sugar for which the probable assignments are O-H, O-H, C-H (stretch), C-H, C-H, intra-molecular O-H hydrogen bonds, intra-molecular O-H hydrogen bonds, intra-molecular O-H hydrogen bonds, intra-molecular O-H hydrogen bonds, CH₂ scissoring modes, C-H, C-H, O-H, C-H, C-O stretch, O-H, C-O-C antisymmetric stretch, C-O stretching modes, C-O stretching modes, C-C, CH=CH₂, O-C-C, CH=CH₂, C-O, O-C-C, Ring glucofuran, O-C-O and O-C-O respectively.

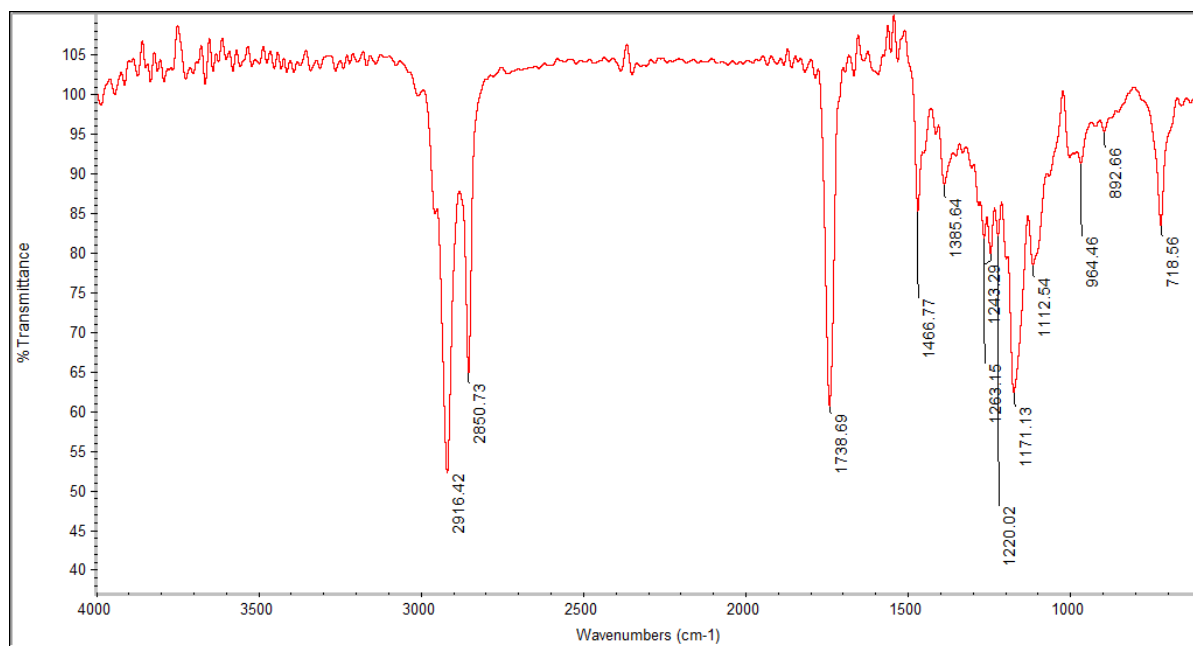


Fig. 4.20. FTIR analysis of shortening (vanaspathi)

The FTIR peaks at 2916 cm^{-1} , 2851 cm^{-1} , 1739 cm^{-1} , 1467 cm^{-1} , 1386 cm^{-1} , 1263 cm^{-1} , 1243 cm^{-1} , 1220 cm^{-1} , 1171 cm^{-1} , 1113 cm^{-1} , 964 cm^{-1} , 893 cm^{-1} and 719 cm^{-1} were obtained for shortening for which the probable assignments are C-H/ CH_2 , C-H (symmetric), C=O, CH_2 bending modes, C-H bending, C-H, C-O, C-O-C antisymmetric stretch, C-O, C=O, C=O, carbohydrate radical from the triglyceride structure and $(\text{CH}_2)_n$ respectively .

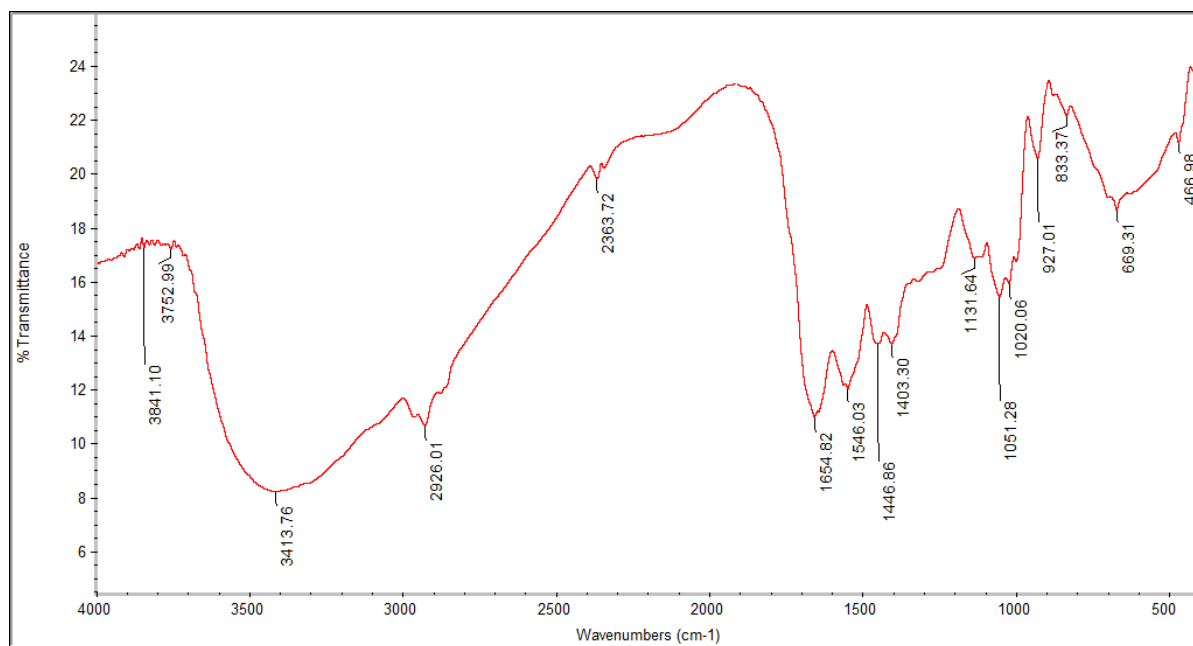


Fig. 4.21. FTIR analysis of FDS powder

The FTIR peaks at 3414 cm^{-1} , 2926 cm^{-1} , 2364 cm^{-1} , 1655 cm^{-1} , 1546 cm^{-1} , 1447 cm^{-1} , 1403 cm^{-1} , 1132 cm^{-1} , 1051 cm^{-1} , 1020 cm^{-1} , 927 cm^{-1} , 833 cm^{-1} , 669 cm^{-1} and 467 cm^{-1} were obtained for FDS powder for which the probable assignments are O-H, C-H/N-H, N=H, C=C/N-H in plane bend, N-H out of plane, C-O stretching vibration, C-H bending, C-O-C antisymmetric stretch, C-O stretching modes, C-O, CH=CH₂ (CH₂ out-of Plane wag), bending vibrations of C-H, C-Br/N-H wag amines and Vibrations of PO₄, respectively. The unidentified peaks were obtained at 3841 cm^{-1} and 3753 cm^{-1} for FDS powder.

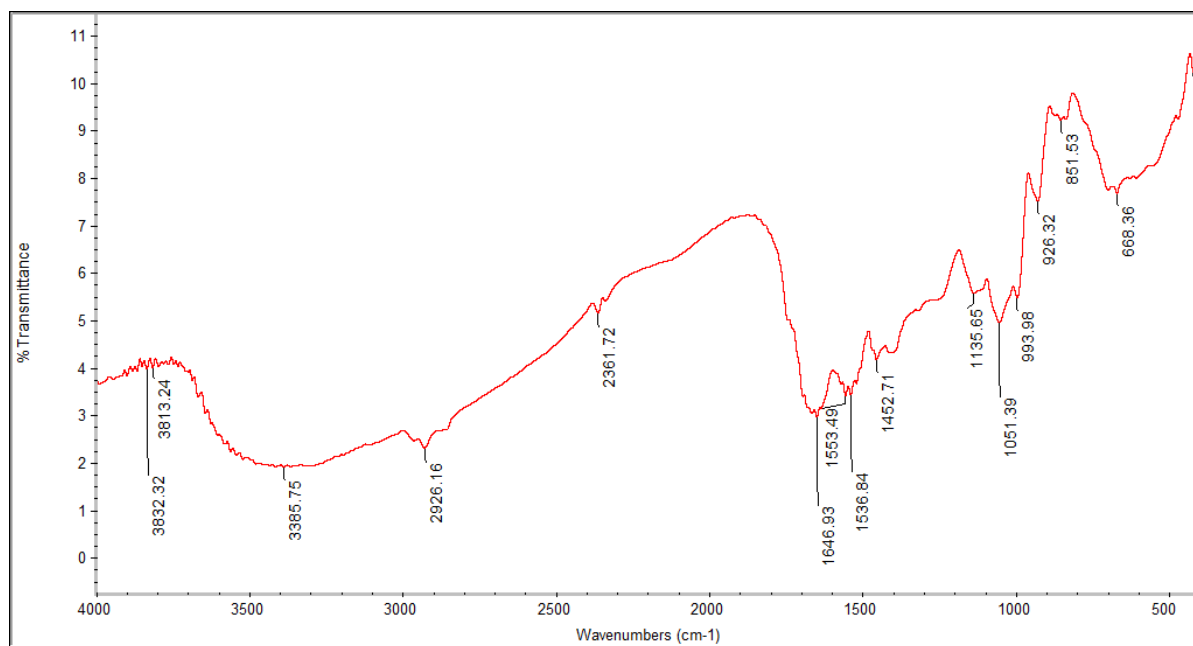


Fig. 4.22. FTIR analysis of ODS powder

The FTIR peaks at 3386 cm^{-1} , 2926 cm^{-1} , 2362 cm^{-1} , 1647 cm^{-1} , 1553 cm^{-1} , 1537 cm^{-1} , 1453 cm^{-1} , 1136 cm^{-1} , 1051 cm^{-1} , 994 cm^{-1} , 926 cm^{-1} , 851 cm^{-1} and 668 cm^{-1} were obtained for ODS powder for which the probable assignments are O-H, C-H/N-H, N=H, C=C/N=H, N-H, C=C in-plane vibration, C-O-C antisymmetric stretch, C-O stretching modes, C-O stretching modes, CH=CH₂ (CH₂ out-of Plane wag), C-H(bend)/ N-H wag amines and C-Br/N-H wag amines, respectively. The unidentified peaks were obtained at 3832 cm^{-1} and 3813 cm^{-1} for ODS powder.

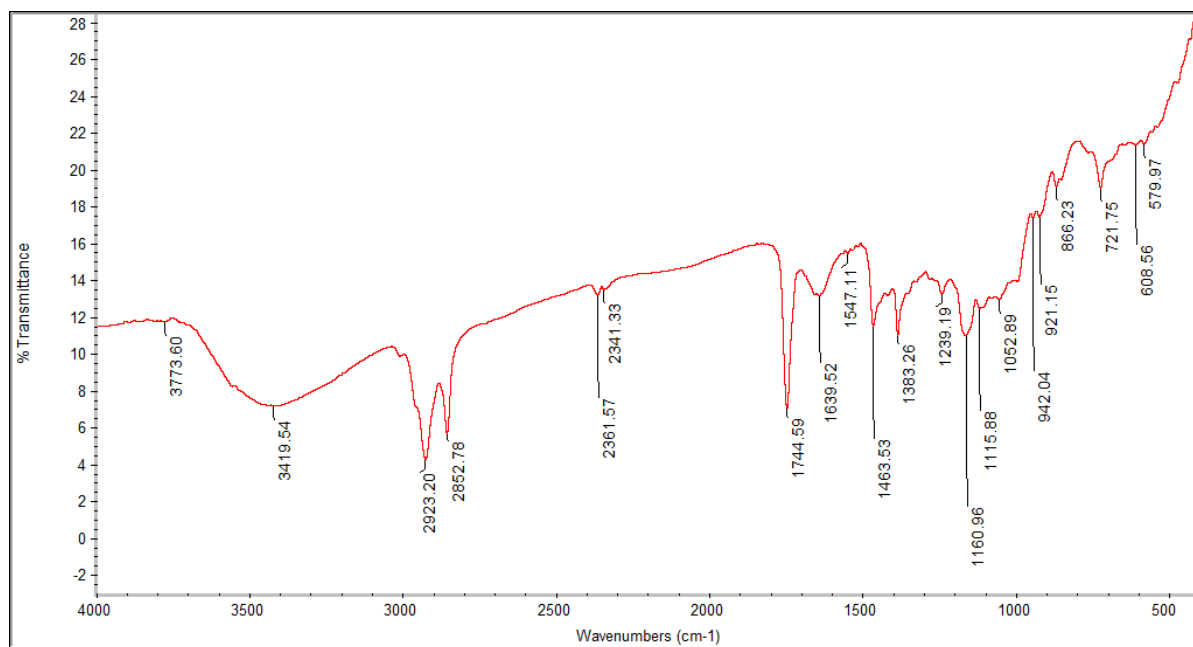


Fig. 4.23. FTIR analysis of Control biscuit

The FTIR peaks at 3419 cm^{-1} , 2923 cm^{-1} , 2853 cm^{-1} , 2362 cm^{-1} , 2341 cm^{-1} , 1745 cm^{-1} , 1640 cm^{-1} , 1547 cm^{-1} , 1464 cm^{-1} , 1383 cm^{-1} , 1239 cm^{-1} , 1161 cm^{-1} , 1116 cm^{-1} , 1053 cm^{-1} , 921 cm^{-1} , 866 cm^{-1} , 722 cm^{-1} , 609 cm^{-1} and 580 cm^{-1} were obtained for control biscuit for which the probable assignments are O-H, C-H/N-H, C-H (symmetric)/N-H, N=H, C-O vibration, C-H stretching/C=O/ Asp-95, C=C/N=H, N-H out of plane, CH_2 bending modes, C-H bending, C-O/C-F stretch, C-F Stretch /C-O/C-N stretch, C-F Stretch /C-O/C-N stretch, C-O stretching modes, $\text{CH}=\text{CH}_2$ (CH_2 out-of Plane wag), C-H(bend)/ N-H wag amines and $(\text{CH}_2)_n$, ν_4 mode of the phosphate group and C-I, respectively. An unidentified peak was obtained at 3774 cm^{-1} for control biscuit.

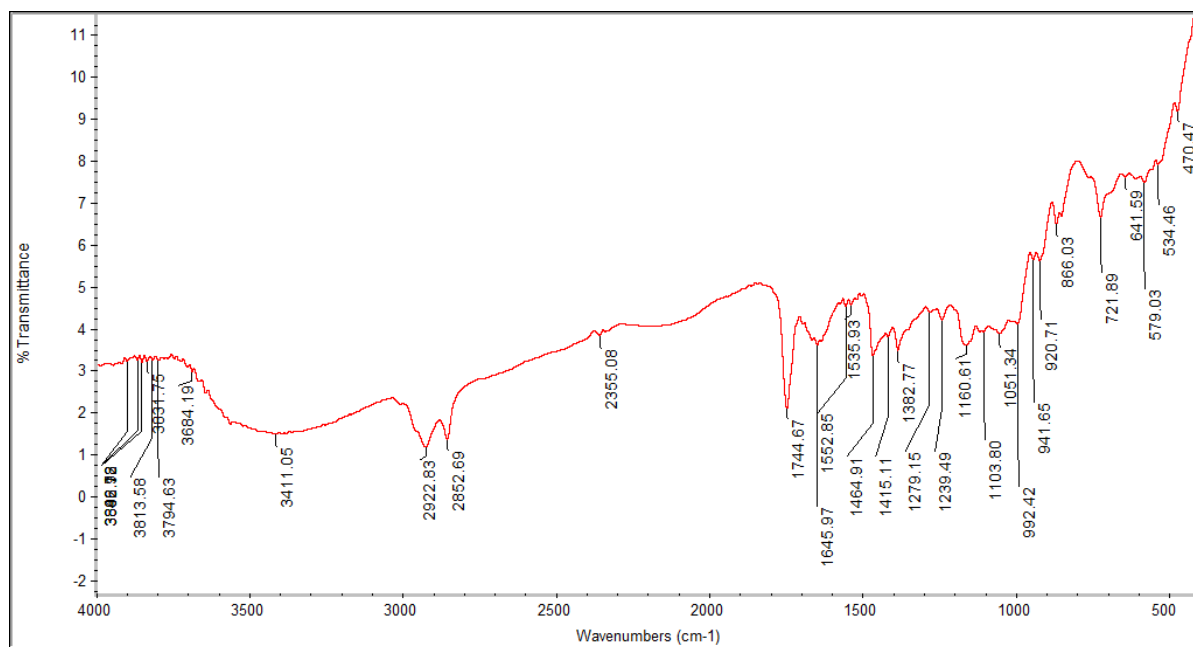


Fig. 4.24. FTIR analysis of FDS Biscuit

The FTIR peaks at 3411 cm^{-1} , 2923 cm^{-1} , 2853 cm^{-1} , 2355 cm^{-1} , 1745 cm^{-1} , 1646 cm^{-1} , 1553 cm^{-1} , 1536 cm^{-1} , 1465 cm^{-1} , 1415 cm^{-1} , 1383 cm^{-1} , 1279 cm^{-1} , 1239 cm^{-1} , 1161 cm^{-1} , 1104 cm^{-1} , 1051 cm^{-1} , 992 cm^{-1} , 942 cm^{-1} , 921 cm^{-1} , 866 cm^{-1} , 722 cm^{-1} , 642 cm^{-1} , 579 cm^{-1} and 470 cm^{-1} were obtained for FDS biscuit for which the probable assignments are O-H, C-H/N-H, C-H (symmetric)/N-H, C-O, C-H stretching/C=O/ Asp-95, C=C/N=H, N-H, N-H stretching vibrations, CH_2 bending modes, C-O stretching and OH deformation of the carboxyl group, C-H bending, C-H, C-O/C-F stretch, C-F Stretch /C-O/C-N stretch, C=O, C-O stretching modes, C-O stretching modes, C-C, $\text{CH}=\text{CH}_2$ (CH_2 out-of Plane wag), C-H(bend)/ N-H wag amines, $(\text{CH}_2)_n$, ring glucofuran, C-I and vibrations of PO_4 , respectively. Unidentified peaks were obtained at 3831 cm^{-1} , 3814 cm^{-1} and 3684 cm^{-1} for FDS biscuit.

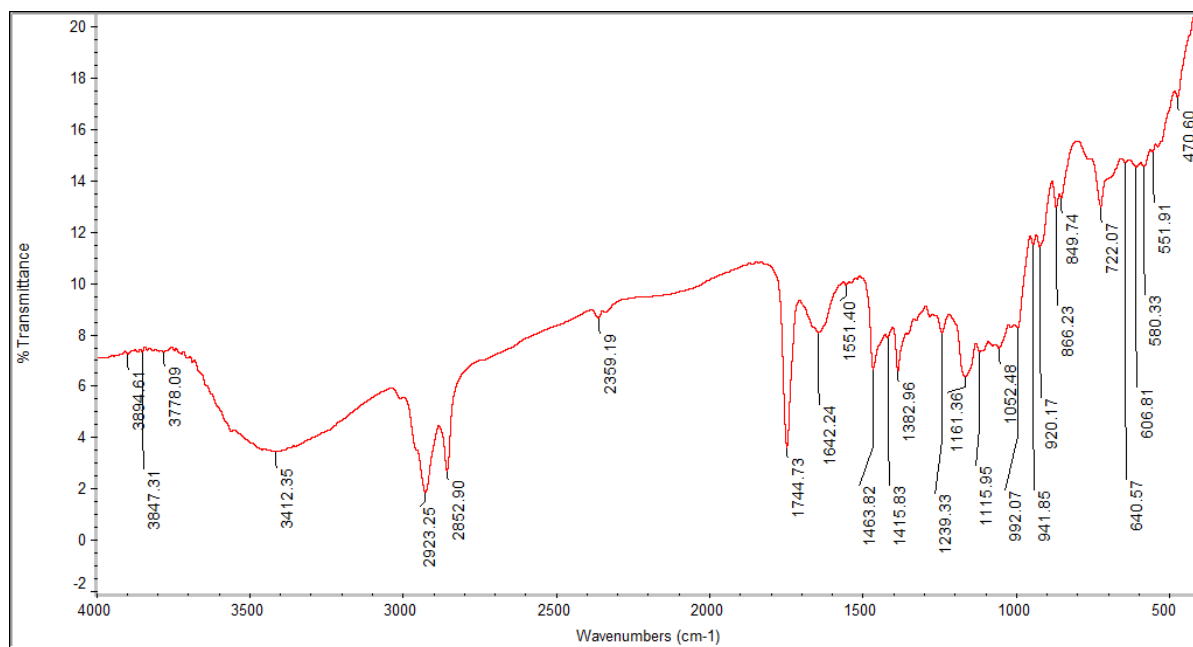


Fig. 4.25. FTIR analysis of ODS Biscuit

The FTIR peaks at 3412 cm^{-1} , 2923 cm^{-1} , 2853 cm^{-1} , 2359 cm^{-1} , 1745 cm^{-1} , 1642 cm^{-1} , 1551 cm^{-1} , 1464 cm^{-1} , 1416 cm^{-1} , 1383 cm^{-1} , 1239 cm^{-1} , 1161 cm^{-1} , 1116 cm^{-1} , 1052 cm^{-1} , 992 cm^{-1} , 942 cm^{-1} , 920 cm^{-1} , 866 cm^{-1} , 850 cm^{-1} , 72 cm^{-1} , 641 cm^{-1} , 607 cm^{-1} , 580 cm^{-1} , 552 cm^{-1} and 470 cm^{-1} were obtained for ODS biscuit for which the probable assignments are O-H, C-H/N-H, C-H (symmetric)/N-H, C-H stretching/C=O/ Asp-95, C=C/N=H, N-H, CH_2 bending modes, C-O stretching and OH deformation of the carboxyl group, C-H bending, C-O/C-F stretch, C-F Stretch /C-O/C-N stretch, C-F Stretch /C-O/C-N stretch, C-O stretching modes, C-O stretching modes, C-C, $\text{CH}=\text{CH}_2$ (CH_2 out-of Plane wag), C-H(bend)/ N-H wag amines, C-H(bend)/ N-H wag amines, $(\text{CH}_2)_n$, ring glucofuran, u4 mode of the phosphate group, C-I, O-C-O and Vibrations of PO_4 , respectively. Unidentified peaks were obtained at 3895 cm^{-1} , 3847 cm^{-1} and 3778 cm^{-1} for ODS biscuit.

Table 4.2. Assignment of FTIR Peaks – Ingredients and biscuits

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
1									3895	
2		3891								
3									3847	
4						3841				
5							3832			
6								3831		
7							3813			
8								3814		
9	3809									
10		3808								
11	3788									
12									3778	

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
13					3774					
14		3772								
15						3753				
16								3684		
17	3680									
18	3657						2362			
19			3562							O-H
20					3419					O-H
21						3414				O-H
22									3412	O-H
23								3411		O-H
24	3410									O-H
25		3397								O-H

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
26			3389							O-H
27							3386			O-H
28			3014							C-H (stretch)
29			2971							C-H
30			2940							C-H
31		2928								C-H/N-H
32						2926	2926			C-H/N-H
33	2924									C-H/N-H
34					2923			2923	2923	C-H/N-H
35				2916						C-H ₀ /CH ₂
36			2913							intra-molecular O-H hydrogen bonds
37	2853				2853			2853	2853	C-H (symmetric)/N-H

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
38				2851						C-H (symmetric)
39			2724							intra-molecular O–H hydrogen bonds
40						2364				N=H
41			2363							intra-molecular O–H hydrogen bonds
42					2362		2362			N=H
43	2361	2361								N=H
44									2359	N=H
45								2355		C-O
46	2341	2341			2341					C-O vibration
47			2126							intra-molecular O–H hydrogen bonds

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
48	1745				1745			1745	1745	C-H stretching/C=O/ Asp-95
49				1739						C=O
50		1657								C=C/N-H in plane blend
51						1655				C=C/N-H in plane blend
52							1647			C=C/N=H
53								1646		C=C/N=H
54									1642	C=C/N=H
55					1640					C=C/N=H
56							1553	1553		N-H
57									1551	N-H
58		1548								N-H out of plane
59					1547					N-H out of plane
60						1546				N-H out of plane

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
61							1537			N-H stretching vibrations
62								1536		N-H stretching vibrations
63	1531									N-H
64				1467						CH ₂ bending modes
65								1465		CH ₂ bending modes
66					1464				1464	CH ₂ bending modes
67			1461							CH ₂ scissoring modes
68							1453			C=C in-plane vibration
69						1447				C–O stretching vibration
70	1443									in-plane mode of N–H
71			1431							C-H

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
72		1425								C-O stretching and OH deformation of the carboxyl group
73									1416	C-O stretching and OH deformation of the carboxyl group
74								1415		C-O stretching and OH deformation of the carboxyl group
75						1403				C-H bending
76				1386						C-H bending
77	1383				1383			1383	1383	C-H bending
78		1382								C-H bending

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
79			1369							C-H
80			1346							O-H
81			1323							C-H
82								1279		C-H
83				1263						C-H
84	1252									C-F Stretch
85		1243		1243						C-O
86					1239			1239	1239	C-O/C-F stretch
87			1238							C-O stretch
88				1220						C-O-C antisymmetric stretch
89			1209							O-H
90				1171						C-O
91					1161			1161	1161	C-F Stretch /C-O/C-N stretch

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
92	1157									C-F Stretch /C-O/C-N stretch
93		1155								C-F Stretch /C-O/C-N stretch
94							1136			C-O-C antisymmetric stretch
95						1132				C-O-C antisymmetric stretch
96			1128							C-O-C antisymmetric stretch
97					1116				1116	C-F Stretch /C-O/C-N stretch
98				1113						C=O
99								1104		C=O
100		1081								P=O stretching/C-F Stretch /C-O/C-N stretch
101			1069							C-O stretching modes
102					1053					C-O stretching modes
103									1052	C-O stretching modes

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
104						1051	1051	1051		C-O stretching modes
105	1022									C-O
106		1020				1020				C-O
107							994			C-O stretching modes
108								992	992	C-O stretching modes
109			990							C-O stretching modes
110				964						C=O
111			942					942	942	C-C
112		929								CH=CH ₂ (CH ₂ out-of Plane wag)
113						927				CH=CH ₂ (CH ₂ out-of Plane wag)

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
114							926			CH=CH ₂ (CH ₂ out-of Plane wag)
115					921			921		CH=CH ₂ (CH ₂ out-of Plane wag)
116									920	CH=CH ₂ (CH ₂ out-of Plane wag)
117			910							CH=CH ₂
118				893						carbohydrate radical from the triglyceride structure
119			867							O-C-C
120					866			866	866	C-H(bend)/ N-H wag amines
121		860								C-H(bend)/ N-H wag amines
122							851			C-H(bend)/ N-H wag amines

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
123									850	C-H(bend)/ N-H wag amines
124			849							CH=CH ₂
125						833				bending vibrations of C-H
126	780									C-H out of plane vibration
127		764								C-C
128			731							C-O
129					722			722	722	(CH ₂) _n
130				719						(CH ₂) _n
131		707								C-H
132			683							O-C-C
133	669	669				669				C-Br/N-H wag amines
134							668			C-Br/N-H wag amines
135			642					642		Ring glucofuran

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
136									641	Ring glucofuran
137					609					u4 mode of the phosphate group
138									607	u4 mode of the phosphate group
139					580				580	C-I
140								579		C-I
141		576								C-I
142			552						552	O-C-O
143								534		C-I
144		529								C-I
145			471							O-C-C

Table 4.2. Cont'd.

Sl. No.	Cocoa powder	Maida	Sugar	Shortening	Control biscuit	FDS powder	ODS powder	FDS biscuit	ODS biscuit	Assignment
146								470	470	Vibrations of PO4
147						467				Vibrations of PO4
148	466									Vibrations of PO4

4.2.7. Organoleptic evaluation of biscuits during storage

The sensory evaluation of control biscuit, biscuit incorporated with FDS powder and that incorporated with ODS powder were estimated during storage and the results are given in Table 4.3, Table 4.4 and Table 4.5.

The organoleptic quality of the control biscuit decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.90 ± 0.31 , 8.97 ± 0.18 , 8.83 ± 0.38 , 8.90 ± 0.31 , 8.80 ± 0.48 , 8.73 ± 0.52 , 8.83 ± 0.38 and 8.90 ± 0.31 , respectively on the 0th day to 7.03 ± 0.49 , 7.13 ± 0.51 , 7.07 ± 0.45 , 6.77 ± 0.43 , 6.53 ± 0.51 , 6.80 ± 0.41 , 6.33 ± 0.48 and 6.70 ± 0.47 , respectively on the 120th day. The organoleptic quality of the biscuit incorporated with FDS powder decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.90 ± 0.31 , 8.97 ± 0.18 , 8.73 ± 0.45 , 8.83 ± 0.38 , 8.73 ± 0.52 , 8.70 ± 0.53 , 8.70 ± 0.47 and 8.83 ± 0.38 , respectively on the 0th day to 6.50 ± 0.51 , 6.47 ± 0.51 , 6.20 ± 0.48 , 5.67 ± 0.48 , 4.63 ± 0.61 , 4.93 ± 0.91 , 4.67 ± 0.48 and 4.53 ± 0.51 , respectively on the 120th day. The organoleptic quality of the biscuit incorporated with ODS powder decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.90 ± 0.31 , 8.97 ± 0.18 , 8.67 ± 0.48 , 8.83 ± 0.38 , 8.70 ± 0.53 , 8.70 ± 0.53 , 8.70 ± 0.47 and 8.83 ± 0.38 , respectively on the 0th day to 6.60 ± 0.50 , 6.53 ± 0.51 , 6.27 ± 0.45 , 5.70 ± 0.47 , 4.87 ± 0.68 , 5.07 ± 0.91 , 4.77 ± 0.43 and 4.67 ± 0.55 , respectively on the 120th day.

Table 4.3. Organoleptic evaluation of control biscuit during storage

	Attributes							
	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
Day 0	8.90 ± 0.31	8.97 ± 0.18	8.83 ± 0.38	8.90 ± 0.31	8.80 ± 0.48	8.73 ± 0.52	8.83 ± 0.38	8.90 ± 0.31
Day 20	8.53 ± 0.51	8.63 ± 0.49	8.27 ± 0.45	8.13 ± 0.35	8.17 ± 0.38	8.23 ± 0.50	8.40 ± 0.56	8.47 ± 0.51
Day 40	8.30 ± 0.47	8.27 ± 0.45	7.97 ± 0.41	8.03 ± 0.41	7.90 ± 0.40	7.73 ± 0.45	7.73 ± 0.45	7.77 ± 0.43
Day 60	7.90 ± 0.31	7.87 ± 0.35	7.80 ± 0.41	7.80 ± 0.41	7.73 ± 0.45	7.53 ± 0.51	7.50 ± 0.57	7.60 ± 0.50
Day 80	7.60 ± 0.50	7.60 ± 0.50	7.63 ± 0.49	7.43 ± 0.63	7.37 ± 0.49	7.17 ± 0.59	7.23 ± 0.57	7.37 ± 0.67
Day 100	7.30 ± 0.53	7.40 ± 0.50	7.30 ± 0.47	7.07 ± 0.45	7.10 ± 0.48	7.17 ± 0.59	7.07 ± 0.58	7.13 ± 0.63
Day 120	7.03 ± 0.49	7.13 ± 0.51	7.07 ± 0.45	6.77 ± 0.43	6.53 ± 0.51	6.80 ± 0.41	6.33 ± 0.48	6.70 ± 0.47

Table 4.4. Organoleptic evaluation of biscuit incorporated with FDS powder during storage

	Attributes							
	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
day 0	8.90 ± 0.31	8.97 ± 0.18	8.73 ± 0.45	8.83 ± 0.38	8.73 ± 0.52	8.70 ± 0.53	8.70 ± 0.47	8.83 ± 0.38
day 20	8.27 ± 0.45	8.13 ± 0.35	8.00 ± 0.45	7.83 ± 0.38	7.67 ± 0.48	7.77 ± 0.43	7.73 ± 0.45	7.70 ± 0.47
day 40	7.60 ± 0.50	7.73 ± 0.45	7.60 ± 0.50	7.37 ± 0.61	7.50 ± 0.51	7.33 ± 0.61	7.27 ± 0.74	7.33 ± 0.61
day 60	7.40 ± 0.50	7.57 ± 0.50	7.33 ± 0.48	6.93 ± 0.52	7.10 ± 0.55	6.83 ± 0.46	6.93 ± 0.52	7.00 ± 0.37
day 80	7.10 ± 0.31	7.50 ± 0.51	6.87 ± 0.51	6.67 ± 0.48	6.10 ± 0.61	6.23 ± 0.77	6.33 ± 0.61	6.20 ± 0.66
day 100	6.80 ± 0.41	6.73 ± 0.45	6.73 ± 0.45	6.13 ± 0.68	5.53 ± 0.51	5.83 ± 0.46	5.17 ± 0.65	5.17 ± 0.75
day 120	6.50 ± 0.51	6.47 ± 0.51	6.20 ± 0.48	5.67 ± 0.48	4.63 ± 0.61	4.93 ± 0.91	4.67 ± 0.48	4.53 ± 0.51

Table 4.5. Organoleptic evaluation of biscuit incorporated with ODS powder during storage

	Attributes							
	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
day 0	8.90 ±0.31	8.97 ± 0.18	8.67 ± 0.48	8.83 ± 0.38	8.70 ± 0.53	8.70 ± 0.53	8.70 ± 0.47	8.83 ± 0.38
day 20	8.33 ± 0.55	8.23 ± 0.43	8.10 ± 0.48	7.90 ± 0.31	7.77 ± 0.43	7.87 ± 0.35	7.83 ± 0.38	7.87 ± 0.35
day 40	7.67 ± 0.48	7.87 ± 0.35	7.70 ± 0.47	7.43 ± 0.63	7.53 ± 0.51	7.40 ± 0.67	7.37 ± 0.76	7.47 ± 0.63
day 60	7.53 ± 0.51	7.70 ± 0.47	7.40 ± 0.50	7.13 ± 0.57	7.23 ± 0.57	7.00 ± 0.59	7.07 ± 0.64	7.07 ± 0.45
day 80	7.17 ±0.38	7.57 ± 0.50	7.00 ± 0.64	6.77 ± 0.43	6.20 ± 0.66	6.37 ± 0.81	6.43 ± 0.63	6.37 ± 0.72
day 100	6.87 ±0.35	6.80 ± 0.41	6.77 ± 0.43	6.20 ± 0.71	5.67 ± 0.61	5.87 ± 0.57	5.33 ± 0.66	5.27 ± 0.78
day 120	6.60 ±0.50	6.53 ± 0.51	6.27 ± 0.45	5.70 ± 0.47	4.87 ± 0.68	5.07 ± 0.91	4.77 ± 0.43	4.67 ± 0.55

4.2.8 Amino acid composition of biscuits

The amino acid composition of biscuits were analysed and the results are given in Table 4.6

Table 4.6. Amino acid composition of biscuits

EAAs	Control biscuit (g/100 g)	ODS biscuit (g/100 g)	FDS biscuit (g/100 g)
Lysine	0.21	0.31	0.33
Therionine	0.15	0.45	0.52
Valine	0.24	0.34	0.32
Methionine	0.08	0.14	0.16
Isolucine	0.19	0.42	0.36
Phenylalanine	0.22	0.34	0.32
Histidine	0.09	0.24	0.20
Tyrosine	0.15	0.12	0.14
Cysteine	0.07	0.11	0.10
Leucine	0.47	0.68	0.66
Total EAAs	2.00	3.15	3.11
NEAA			
Aspartic acid	0.33	0.54	0.56
Glutamic acid	0.96	1.77	1.80
Arginine	0.23	0.39	0.35
Serine	0.25	0.58	0.58

Table 4.6. cont'd

NEAA	Control biscuit (g/100 g)	ODS biscuit (g/100 g)	FDS biscuit (g/100 g)
Proline	0.29	0.21	0.21
Glycine	0.15	0.38	0.39
Alanine	0.18	0.35	0.36
Total NEAAs	2.39	4.15	4.25
Total AM	4.39	7.30	7.36

An increase in amino acid content in the biscuit was seen in surimi incorporated biscuits.

4.2.9 Minerals in biscuits

The mineral content in biscuits was analysed and the results are given in Table 4.7.

Table 4.7. Minerals in biscuits

Mineral	Control biscuits ($\times 10^{-2}$ g kg⁻¹)	ODS Biscuit ($\times 10^{-2}$ g kg⁻¹)	FDS Biscuit ($\times 10^{-2}$ g kg⁻¹)
Phosphorus	71 $\pm$ 4	82 $\pm$ 18	79 $\pm$ 13
Calcium	1.4 $\pm$ 0.1	5.8 $\pm$ 0.5	6.2 $\pm$ 1.8
Zinc	1.6 $\pm$ 0.8	1.2 $\pm$ 0.6	1.7 $\pm$ 0.6
Iron	4.2 $\pm$ 0.2	6.1 $\pm$ 0.5	5.8 $\pm$ 0.5

The phosphorus, calcium, zinc and iron content were $(71 \pm 4) \times 10^{-2}$ g/kg, $(1.4 \pm 0.1) \times 10^{-2}$ g/kg, $(1.6 \pm 0.8) \times 10^{-2}$ g/kg and $(4.2 \pm 0.2) \times 10^{-2}$ g/kg, respectively in control biscuit, $(82 \pm 18) \times 10^{-2}$ g/kg, $(5.8 \pm 0.5) \times 10^{-2}$ g/kg, $(1.2 \pm 0.6) \times 10^{-2}$ g/kg and (6.1 ± 0.5) , respectively in ODS Biscuit and $(79 \pm 13) \times 10^{-2}$ g/kg, $(6.2 \pm 1.8) \times 10^{-2}$ g/kg, (1.7 ± 0.6) and $(5.8 \pm 0.5) \times 10^{-2}$ g/kg in FDS Biscuit.

4.3 Bread

Breads were prepared by incorporating different proportions (5%, 10% and 15%) of FDS and ODS powder and their various characteristics were evaluated.

4.3.1 Proximate composition of bread with surimi powder

The proximate composition of bread incorporated with FDS powder and that incorporated with ODS powder were estimated and the results are given in Fig. 4.26 and Fig. 4.27, respectively.

The moisture, ash, fat, protein and carbohydrates content in control bread were $20.49 \pm 0.07\%$, $0.30 \pm 0.00\%$, $3.46 \pm 0.02\%$, $8.06 \pm 0.08\%$ and $67.69 \pm 0.07\%$, respectively, while in bread incorporated with 5% FDS powder were $20.41 \pm 0.10\%$, $0.46 \pm 0.06\%$, $3.51 \pm 0.10\%$, 10.55 ± 0.31 and $65.07 \pm 0.38\%$, respectively, in bread incorporated with 10% FDS powder were $20.45 \pm 0.19\%$, $0.73 \pm 0.06\%$, $3.62 \pm 0.03\%$, $13.36 \pm 0.04\%$ and $61.84 \pm 0.23\%$, respectively and in bread incorporated with 15% FDS powder were $20.65 \pm 0.05\%$, $0.93 \pm 0.06\%$, $3.63 \pm 0.06\%$, $15.14 \pm 0.21\%$ and $59.66 \pm 0.29\%$, respectively.

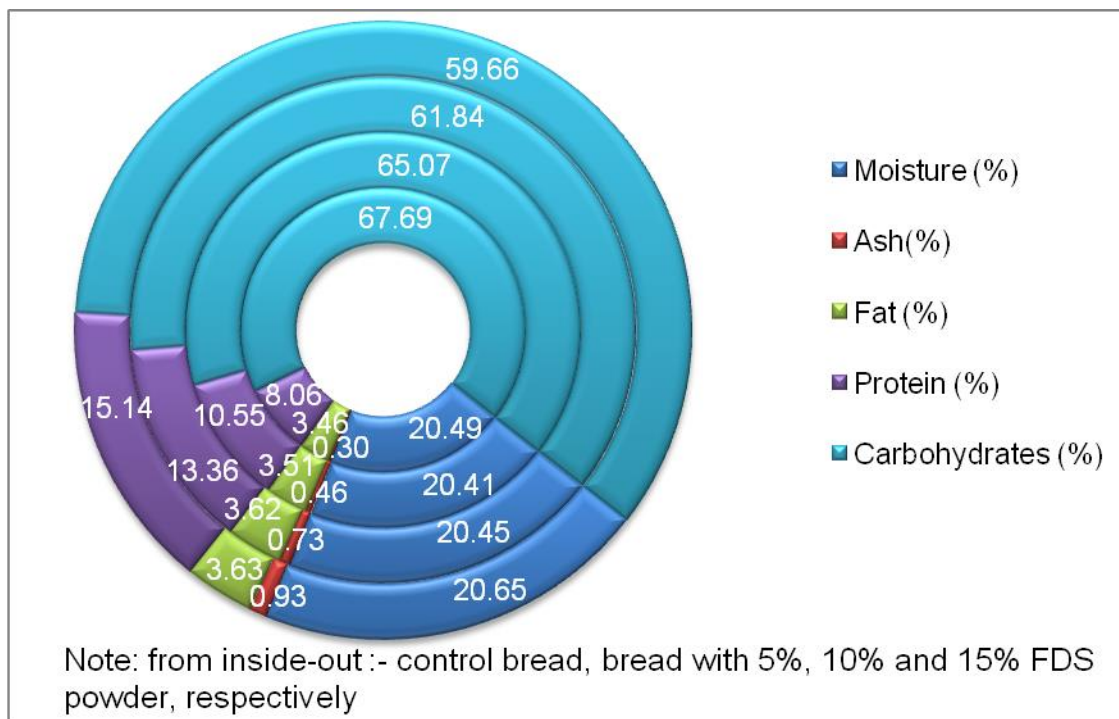


Fig. 4.26. Proximate composition of bread with FDS powder

The moisture, ash, fat, protein and carbohydrates content in control bread were $20.49 \pm 0.07\%$, $0.30 \pm 0.00\%$, $3.46 \pm 0.02\%$, $8.06 \pm 0.08\%$ and $67.69 \pm 0.07\%$, respectively, while in bread incorporated with 5% ODS powder were $20.43 \pm 0.07\%$, $0.43 \pm 0.12\%$, $3.57 \pm 0.06\%$, $10.38 \pm 0.23\%$ and $65.19 \pm 0.44\%$, respectively, in bread incorporated with 10% ODS powder were $20.73 \pm 0.16\%$, $0.63 \pm 0.06\%$, $3.54 \pm 0.02\%$, $13.21 \pm 0.11\%$ and $61.89 \pm 0.28\%$, respectively and in bread incorporated with 15% ODS powder were $20.38 \pm 0.27\%$, $0.80 \pm 0.10\%$, $3.61 \pm 0.05\%$, $14.45 \pm 0.20\%$ and $60.76 \pm 0.47\%$, respectively.

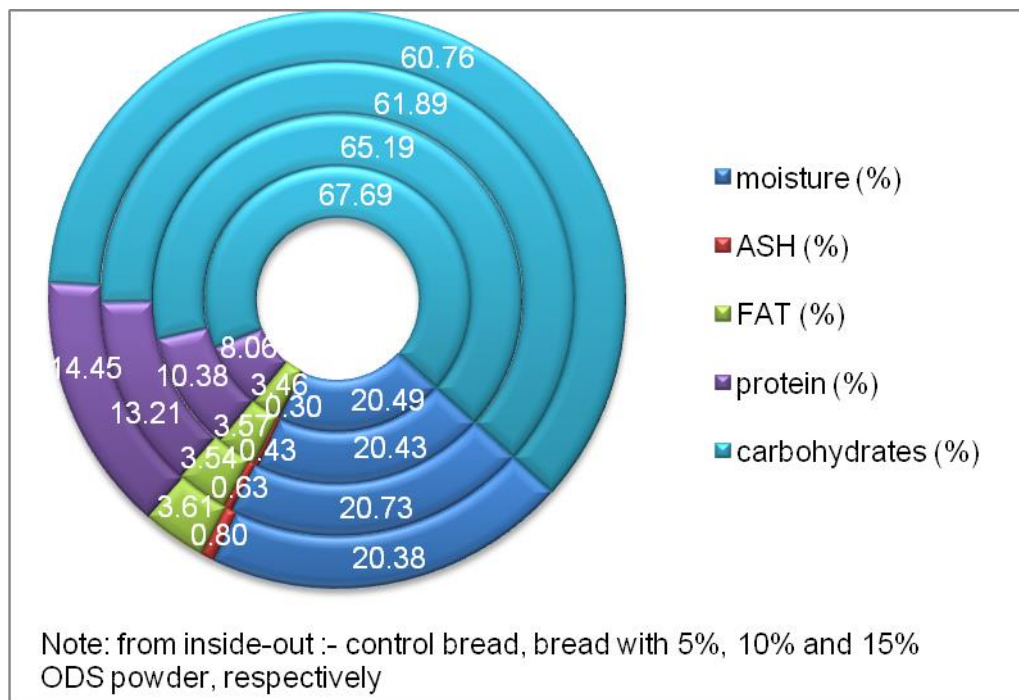


Fig. 4.27. Proximate composition of bread with ODS powder

4.3.2 Sensory evaluation of bread incorporated with surimi powder

The sensory evaluation of bread incorporated with FDS powder and that incorporated with ODS powder were estimated and the results are given in Fig. 4.28. and Fig. 4.29., respectively.

The sensory scores on an average for control bread, bread incorporated with 5%, 10% and 15% FDS powder were 8.77 ± 0.43 , 8.43 ± 0.50 , 8.33 ± 0.48 and 7.27 ± 0.45 , respectively for the attribute appearance, 8.90 ± 0.31 , 8.47 ± 0.51 , 8.37 ± 0.49 and 6.70 ± 0.47 , respectively for the attribute colour, 8.80 ± 0.41 , 8.60 ± 0.50 , 8.43 ± 0.50 and 5.30 ± 0.47 , respectively for the attribute odour, 8.83 ± 0.38 , 8.70 ± 0.47 , 8.57 ± 0.50 and 4.67 ± 0.48 , respectively for the attribute taste,

8.80 $\pm$ 0.41, 8.67 $\pm$ 0.48, 8.57 $\pm$ 0.50 and 6.23 $\pm$ 0.43, respectively for the attribute mouth feel, 8.73 $\pm$ 0.45, 8.57 $\pm$ 0.50, 8.43 $\pm$ 0.50 and 4.60 $\pm$ 0.50, respectively for the attribute flavour, 8.80 $\pm$ 0.41, 8.73 $\pm$ 0.45, 8.63 $\pm$ 0.49 and 6.27 $\pm$ 0.45, respectively for the attribute texture and, 8.77 $\pm$ 0.43, 8.50 $\pm$ 0.51, 8.47 $\pm$ 0.51 and 4.60 $\pm$ 0.50, respectively for overall acceptability.

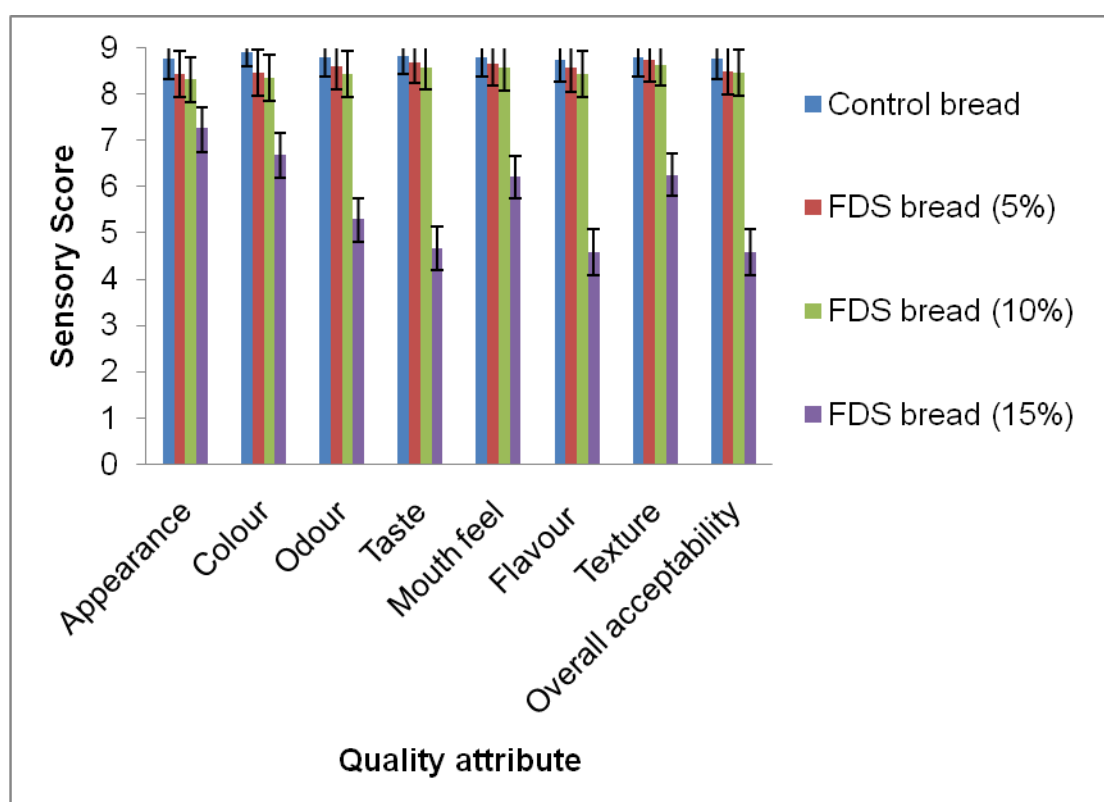


Fig. 4.28. Sensory scores of bread incorporated with FDS powder

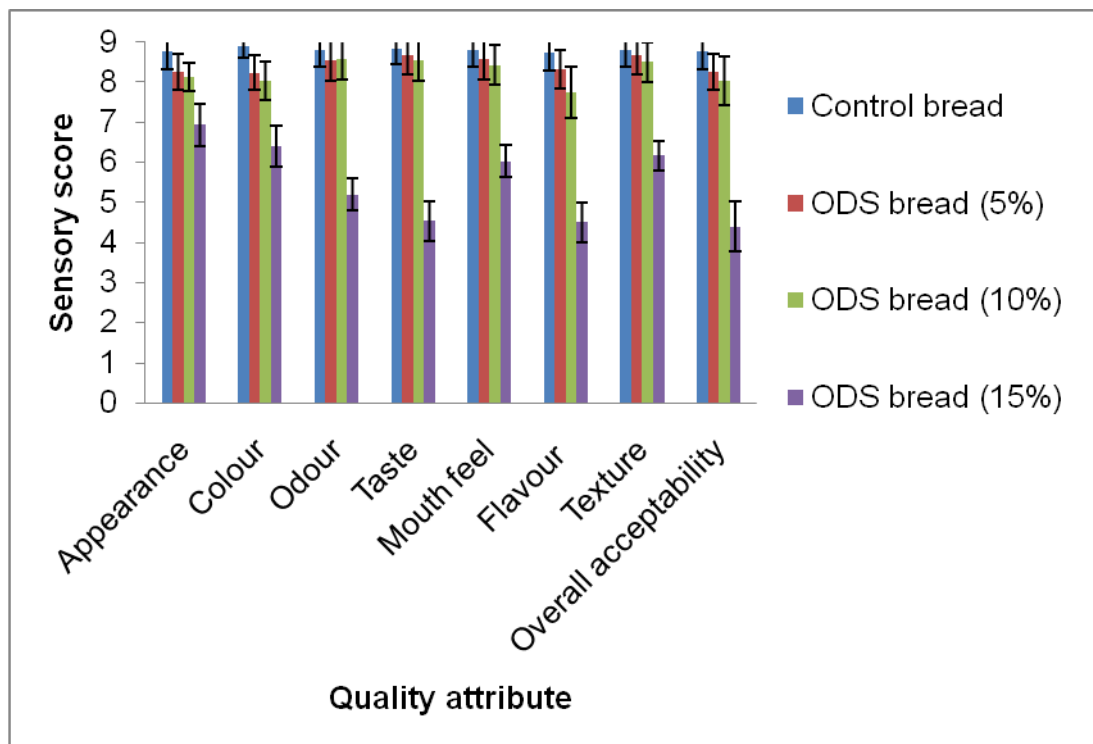


Fig. 4.29. Sensory evaluation of bread incorporated with ODS powder

The sensory scores on an average for control bread, bread incorporated with 5%, 10% and 15% ODS powder were 8.77 ± 0.43 , 8.27 ± 0.45 , 8.13 ± 0.35 and 6.93 ± 0.52 , respectively for the attribute appearance, 8.90 ± 0.31 , 8.23 ± 0.43 , 8.03 ± 0.49 and 6.40 ± 0.50 , respectively for the attribute colour, 8.80 ± 0.41 , 8.53 ± 0.51 , 8.57 ± 0.50 and 5.20 ± 0.41 , respectively for the attribute odour, 8.83 ± 0.38 , 8.67 ± 0.48 , 8.53 ± 0.51 and 4.53 ± 0.51 , respectively for the attribute taste, 8.80 ± 0.41 , 8.57 ± 0.50 , 8.43 ± 0.50 and 6.03 ± 0.41 , respectively for the attribute mouth feel, 8.73 ± 0.45 , 8.33 ± 0.48 , 7.73 ± 0.64 and 4.50 ± 0.51 , respectively for the attribute flavour, 8.80 ± 0.41 , 8.67 ± 0.48 , 8.50 ± 0.51 and 6.17 ± 0.38 , respectively for the attribute texture and, 8.77 ± 0.43 , 8.27 ± 0.45 , 8.03 ± 0.61 and 4.40 ± 0.62 , respectively for overall acceptability.

Plate II. Bread incorporated with surimi powder



Control bread



FDS bread



ODS bread

4.3.3 Microstructure of bread

Scanning electron microscopic images of control bread, bread incorporated with 10% FDS powder and that incorporated with 10% ODS powder were observed and the images are given in Fig. 4.30, Fig. 4.31 and Fig. 4.32, respectively.

Large airspaces were seen in control bread. The sizes of the air spaces in FDS powder and ODS powder added bread were slightly reduced as compared to the control bread. Highly porous structure was a common characteristic feature of all types of bread. Darker surimi powder was visible in ODS bread.

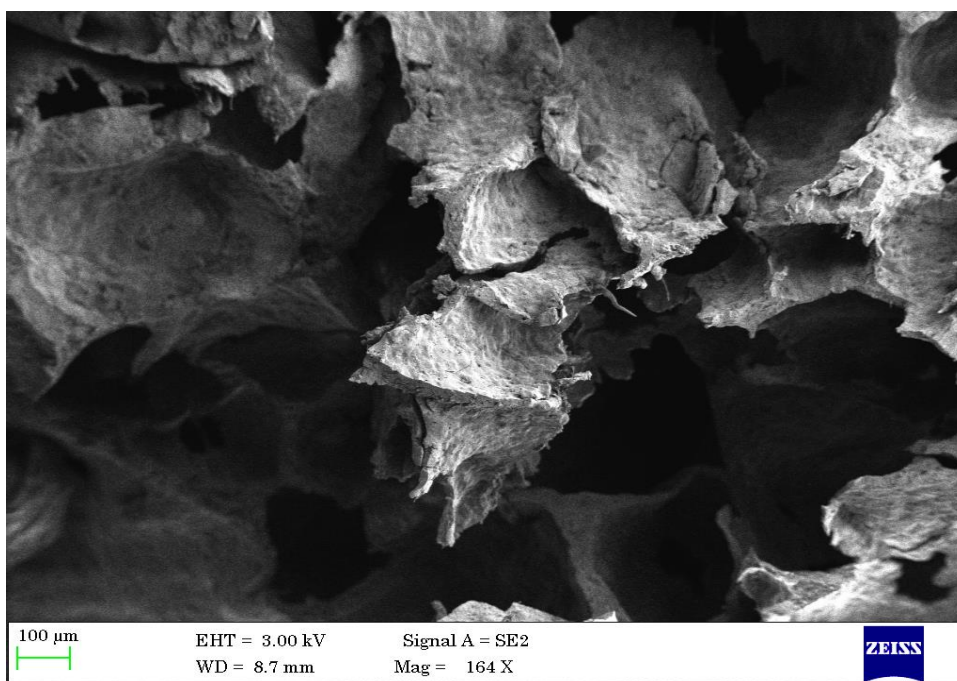


Fig. 4.30 SEM image of control bread

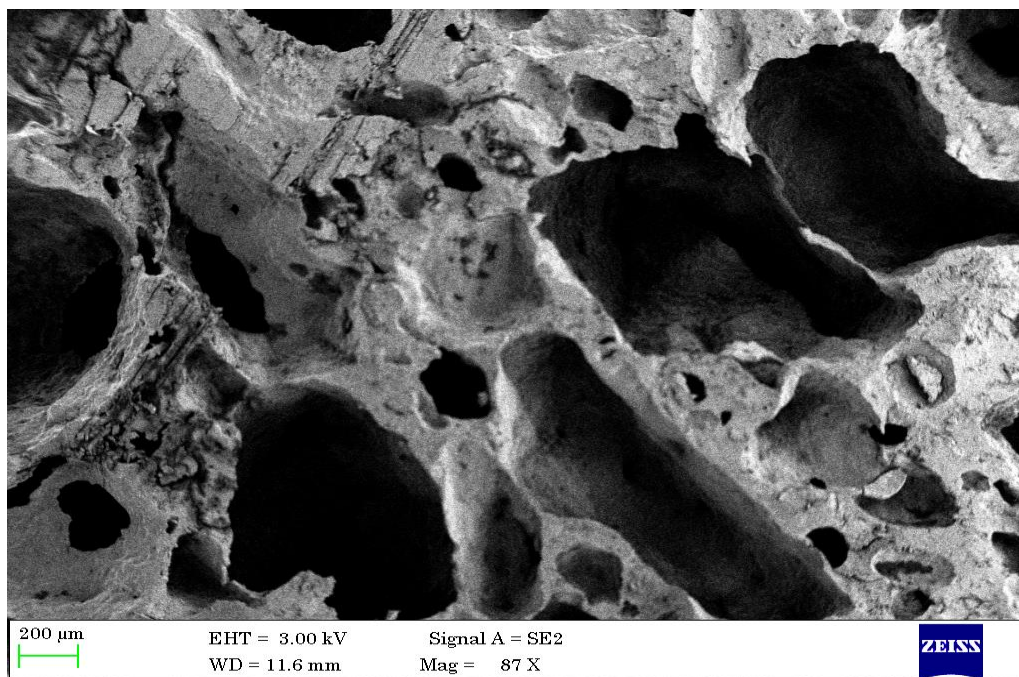


Fig. 4.31 SEM image of FDS bread

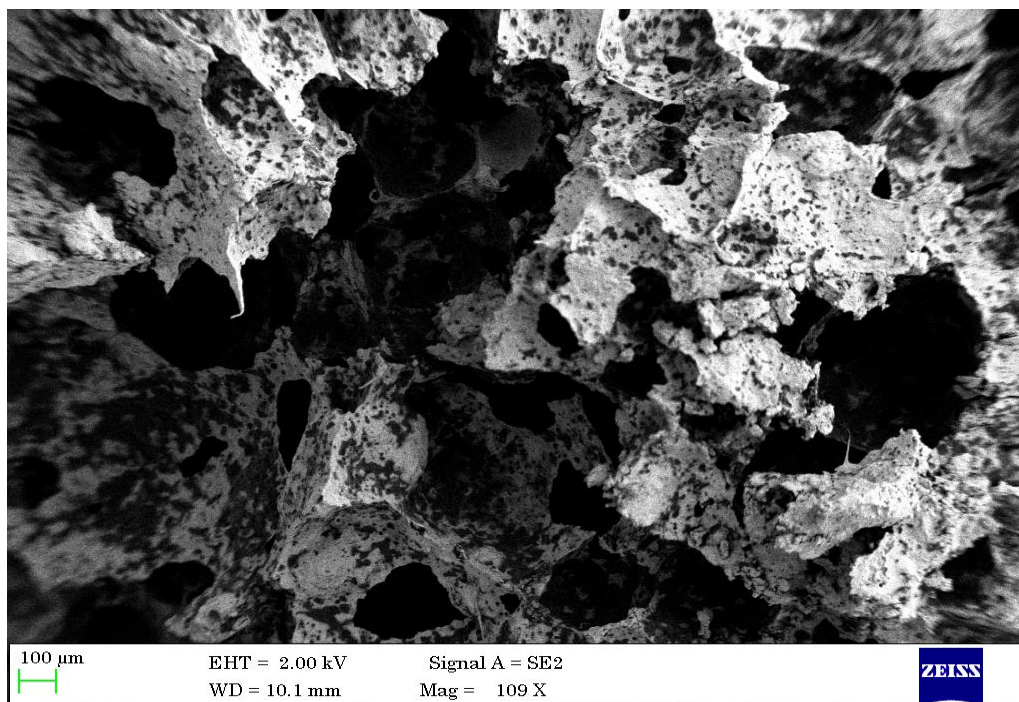


Fig. 4.32 SEM image of ODS bread

4.3.4 Storage stability of bread incorporated with surimi powder

4.3.4.1 TBARS value of bread incorporated with surimi powder during storage

The TBARS values of biscuits incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.33.

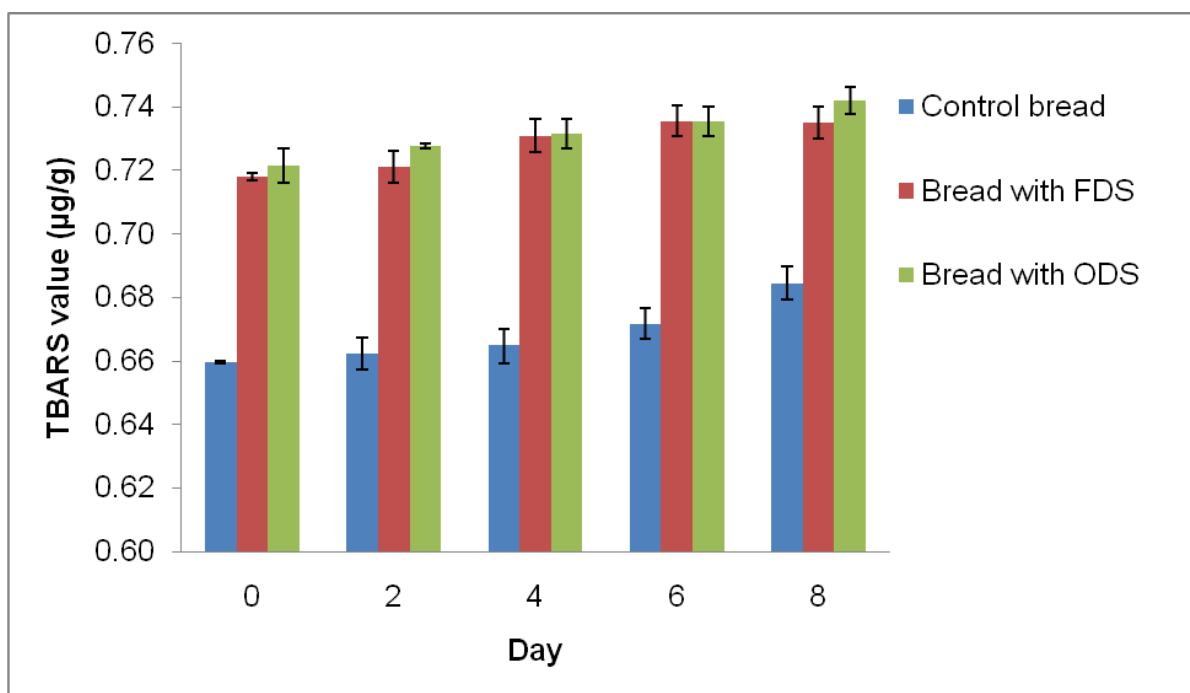


Fig. 4.33. TBARS value of bread during storage

The TBARS values of control bread, bread incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.66 µM/g, 0.72 µM/g and 0.72 µM/g, respectively, which gradually increased to 0.68 µM/g, 0.74 µM/g and 0.74 µM/g, respectively by the 8th day.

4.3.4.2 Peroxide value of bread incorporated with surimi powder during storage

The Peroxide Values of bread incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.34.

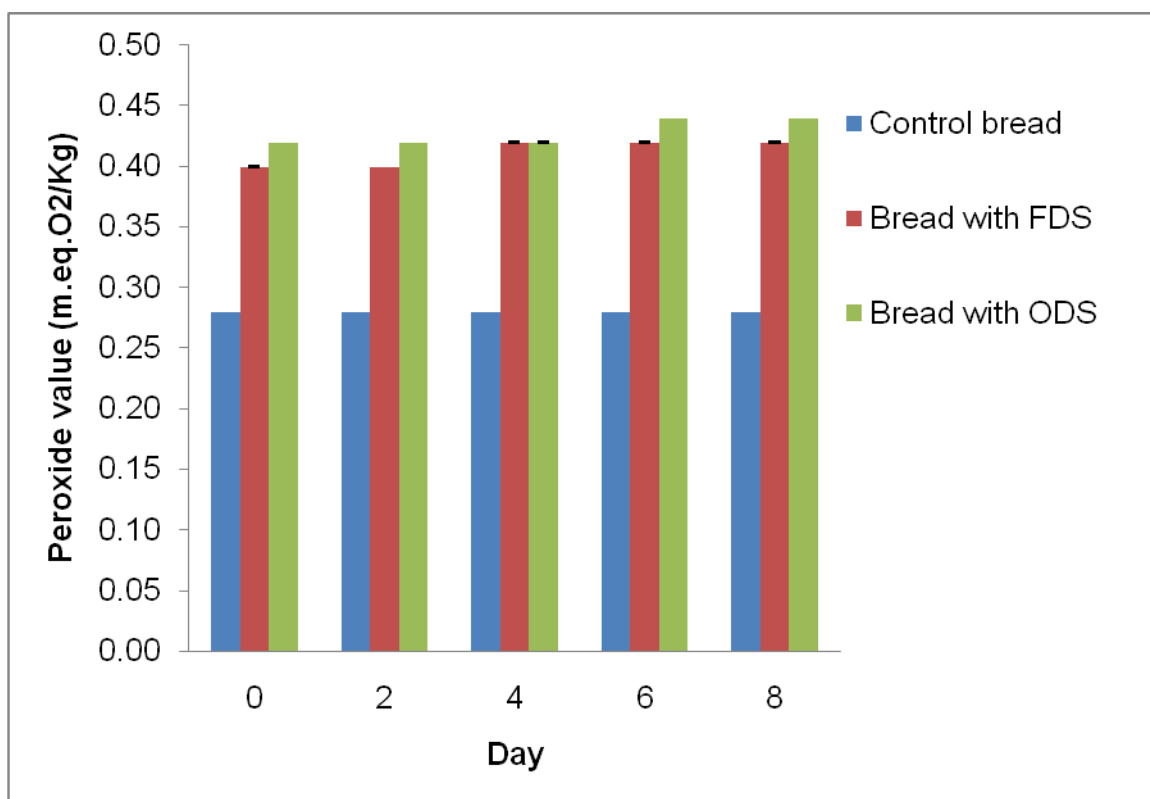


Fig. 4.34. Peroxide value of bread during storage

The peroxide value of control bread was 0.28 m.eq.O₂/Kg and did not increase during storage period. The peroxide values of bread incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.40 m.eq.O₂/Kg and 0.42 m.eq.O₂/Kg, respectively and gradually increased to 0.42 m.eq.O₂/Kg and 0.44 m.eq.O₂/Kg, respectively by the 8th day.

4.3.4.3 Free fatty acid in bread incorporated with surimi powder during storage

The free fatty acid in bread incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.35.

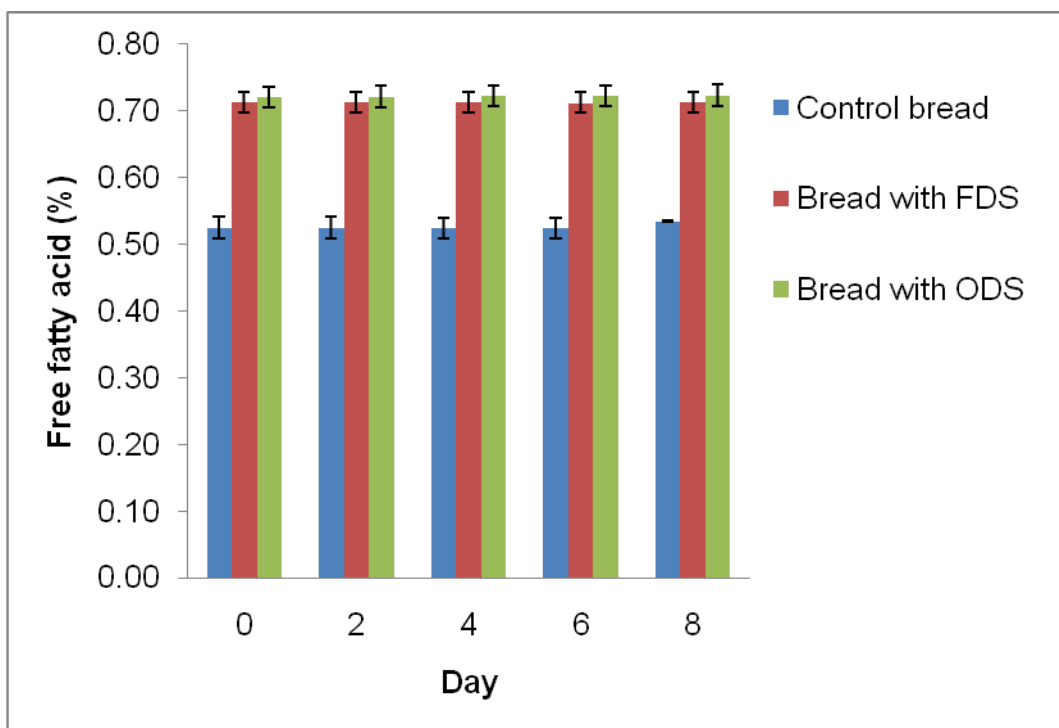


Fig. 4.35. Free fatty acid in bread during storage

The free fatty acid in control bread, bread incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.53 \pm 0.02\%$, $0.71 \pm 0.02\%$ and $0.72 \pm 0.02\%$, respectively and did not vary significantly during a storage period of 8 days.

4.3.5 Microbial quality of bread during storage

The total plate count of control bread, bread incorporated with FDS powder and that incorporated with ODS powder were estimated and the results are given in Fig. 4.36.

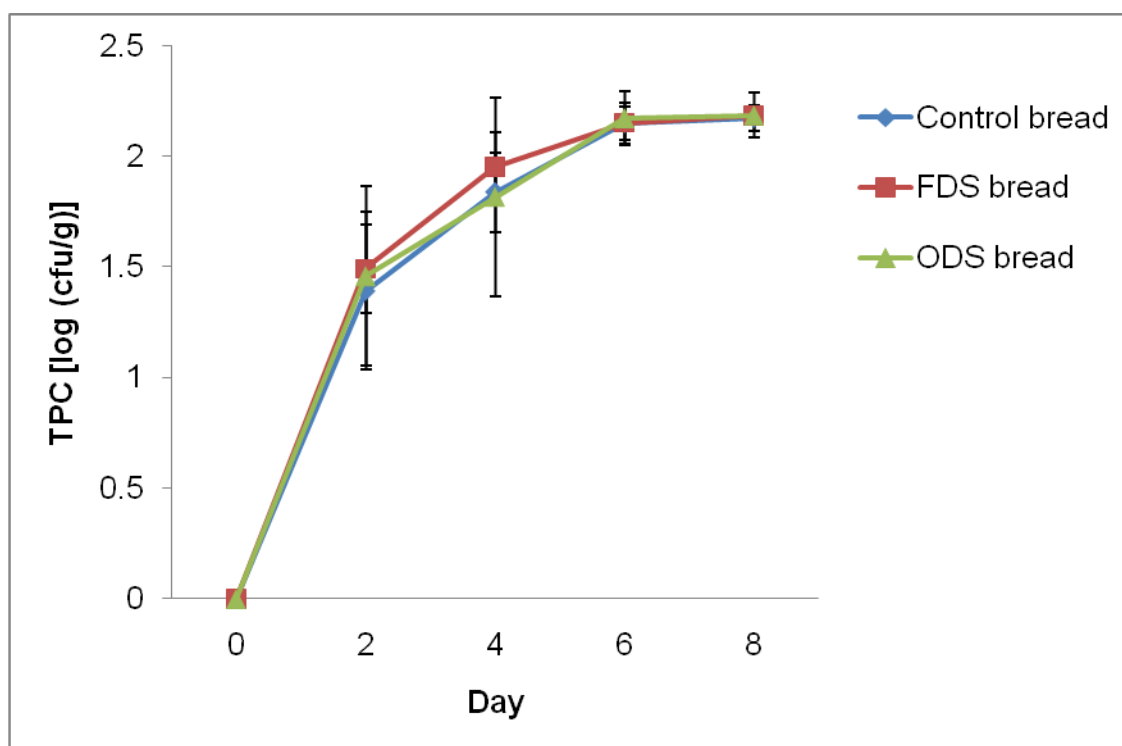


Fig. 4.36. Total plate count of bread.

The total plate count of control bread, bread incorporated with FDS powder and that incorporated with ODS powder were not detected on the 0th day and were 1.39 ± 0.36 logcfu/g, 1.49 ± 0.20 logcfu/g and 1.46 ± 0.41 logcfu/g on the 2nd day and then increased to 2.17 ± 0.06 logcfu/g, 2.18 ± 0.03 logcfu/g and 2.19 ± 0.10

logcfu/g, respectively on the 8th day. Total fungal count was not detected in any of breads.

4.3.6 Fourier Transform Infrared Spectroscopy of bread

FTIR spectrum was analysed to examine the functional interaction that took place during the formulation and processing of breads. The FTIR Spectra were collected in the transmission mode using FTIR Spectrometer for the different ingredients viz. maida, sugar, shortening, FDS powder and ODS powder, and also the final products viz. control bread, bread incorporated with FDS powder and that incorporated with ODS powder and are given in Fig 4.18 to Fig. 4.22 and Fig 4.37 to Fig. 4.39 and the peaks are assigned in Table 4.8.

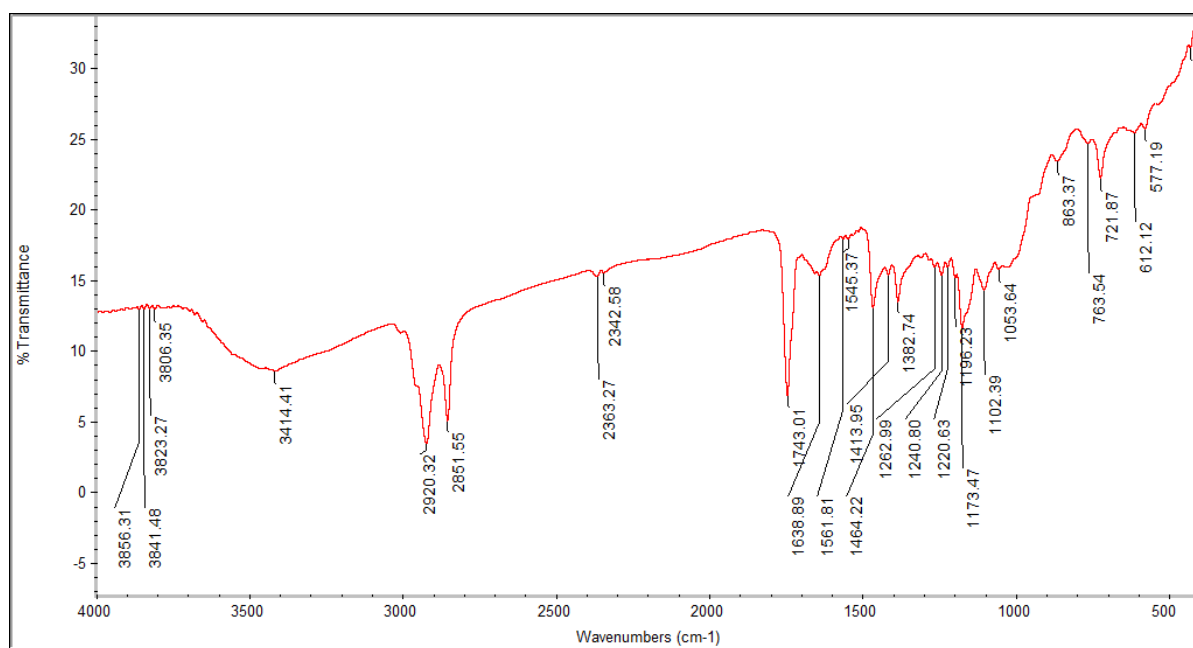


Fig. 4.37. FTIR analysis of Control bread

The FTIR peaks at 3414 cm⁻¹, 3414cm⁻¹, 2363 cm⁻¹, 2343 cm⁻¹, 1743 cm⁻¹, 1639 cm⁻¹, 1562 cm⁻¹, 1545 cm⁻¹, 1464 cm⁻¹, 1414 cm⁻¹, 1383 cm⁻¹, 1263 cm⁻¹, 1241

cm^{-1} , 1221 cm^{-1} , 1196 cm^{-1} , 1173 cm^{-1} , 1102 cm^{-1} , 1054 cm^{-1} , 863 cm^{-1} , 764 cm^{-1} , 722 cm^{-1} , 612 cm^{-1} and 577 cm^{-1} were obtained for control bread for which the probable assignments are O-H, C-H (symmetric)/N-H, intra-molecular O-H hydrogen bonds, C-O vibration, C=O/ Asp-96, C=C/N=H, N-H bending, N-H out of plane, CH_2 bending modes, C-O stretching and OH deformation of the carboxyl group, C-O stretching and OH deformation of the carboxyl group, C-H bending, C-H, C-O/C-F stretch, C-O-C antisymmetric stretch, C-O/C-N stretch/C-F stretch, C-O/C-N stretch/C-F stretch, C=O, C-O stretching modes, C-H(bend)/ N-H wag amines, C-C, $(\text{CH}_2)_n$, u4 mode of the phosphate group and C-I respectively. Unidentified peaks were obtained at 3856 cm^{-1} , 3841 cm^{-1} , 3823 cm^{-1} and 3806 cm^{-1} for control bread.

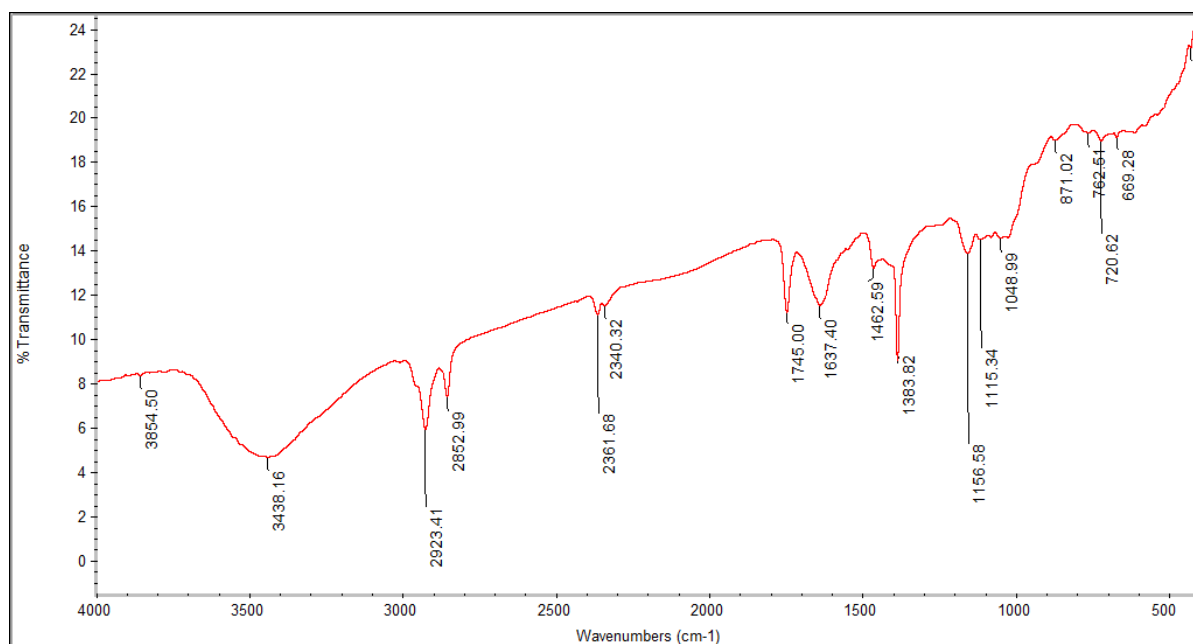


Fig. 4.38. FTIR analysis of FDS bread

The FTIR peaks at 3438 cm^{-1} , 2923 cm^{-1} , 2853 cm^{-1} , 2361 cm^{-1} , 2340 cm^{-1} , 1745 cm^{-1} , 1637 cm^{-1} , 1463 cm^{-1} , 1384 cm^{-1} , 1157 cm^{-1} , 1115 cm^{-1} , 1049 cm^{-1} , 871 cm^{-1} , 763 cm^{-1} , 721 cm^{-1} and 669 cm^{-1} were obtained for FDS bread for which the

probable assignments are O-H, C-H/N-H, C-H (symmetric)/N-H, N=H, C-O vibration, C-H stretching/C=O/ Asp-95, C=C/N=H , CH₂ bending modes, C-H bending, C-F Stretch /C-O/C-N stretch, C-F Stretch /C-O/C-N stretch, C-O stretching modes, C-H(bend), C-C, (CH₂)_n and C-Br/N-H wag amines respectively. An unidentified peak was obtained at 3855 cm⁻¹ for FDS bread.

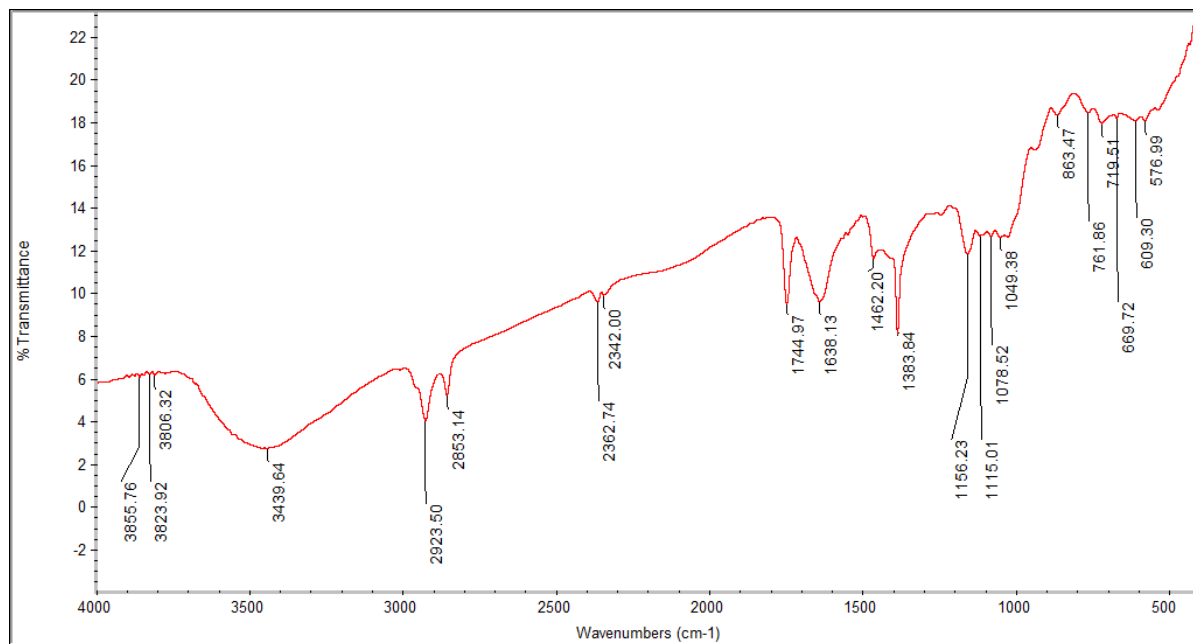


Fig. 4.39. FTIR analysis of ODS bread

The FTIR peaks at 3440 cm⁻¹, 2924 cm⁻¹, 2853 cm⁻¹, 2363 cm⁻¹, 2342 cm⁻¹, 1745 cm⁻¹ , 1638 cm⁻¹, 1462 cm⁻¹, 1384 cm⁻¹, 1156 cm⁻¹, 1115 cm⁻¹, 1079 cm⁻¹ , 1049 cm⁻¹ , 863 cm⁻¹, 762 cm⁻¹, 720 cm⁻¹, 670 cm⁻¹, 609 cm⁻¹ and 577cm⁻¹ were obtained for ODS bread for which the probable assignments are O-H, C-H/N-H, C-H (symmetric)/N-H, intra-molecular O-H hydrogen bonds, C-O vibration, C-H stretching/C=O/ Asp-95, C=C/N=H , CH₂ bending modes, C-H bending, C-F Stretch /C-O/C-N stretch, C-F Stretch /C-O/C-N stretch, P=O stretching/C-F Stretch /C-O/C-N stretch, C-O stretching modes, C-C, (CH₂)_n, C-Br/N-H wag amines, u₄ mode of

the phosphate group and C-I respectively. Unidentified peaks were obtained at 3856 cm^{-1} , 3824 cm^{-1} and 3806 cm^{-1} for ODS bread.

Table 4.8. Assignment of FTIR Peaks – Ingredients and bread

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
1	3891								
2				3856				3856	
3						3855			
4				3841	3841				
5							3832		
6								3824	
7				3823					
8							3813		
9	3808								
10				3806				3806	
11	3772								
12					3753				

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
13							2362		
14		3562							O-H
15								3440	O-H
16						3438			O-H
17				3414	3414				O-H
18	3397								O-H
19		3389							O-H
20							3386		O-H
21		3014							C-H (stretch)
22		2971							C-H
23		2940							C-H
24	2928								C-H/N-H
25					2926		2926		C-H/N-H

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
26								2924	C-H/N-H
27						2923			C-H/N-H
28			2916						C-H ₀ /CH ₂
29		2913							intra-molecular O–H hydrogen bonds
30						2853		2853	C-H (symmetric)/N-H
31				2852					C-H (symmetric)/N-H
32			2851						C-H (symmetric)
33		2724							intra-molecular O–H hydrogen bonds
34					2364				N=H
35		2363		2363				2363	intra-molecular O–H hydrogen bonds
36							2362		N=H
37	2361					2361			N=H
38				2343					C-O vibration

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
39								2342	C-O vibration
40	2341								C-O vibration
41						2340			C-O vibration
42		2126							intra-molecular O–H hydrogen bonds
43						1745		1745	C-H stretching/C=O/ Asp-95
44				1743					C=O/ Asp-96
45			1739						C=O
46	1657								C=C/N-H in plane blend
47					1655				C=C/N-H in plane blend
48							1647		C=C/N=H
49				1639					C=C/N=H
50								1638	C=C/N=H
51						1637			C=C/N=H

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
52				1562					N-H bending
53							1553		N-H
54	1548								N-H out of plane
55					1546				N-H out of plane
56				1545					N-H out of plane
57							1537		N-H stretching vibrations
58			1467						CH ₂ bending modes
59				1464					CH ₂ bending modes
60						1463			CH ₂ bending modes
61								1462	CH ₂ bending modes
62		1461							CH ₂ scissoring modes
63							1453		C=C in-plane vibration
64					1447				C–O stretching vibration

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
65		1431							C-H
66	1425								C-O stretching and OH deformation of the carboxyl group
67				1414					C-O stretching and OH deformation of the carboxyl group
68					1403				C-H bending
69			1386						C-H bending
70						1384		1384	C-H bending
71				1383					C-H bending
72	1382								C-H bending
73		1369							C-H
74		1346							O-H
75		1323							C-H

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
76			1263	1263					C-H
77	1243		1243						C-O
78				1241					C-O/C-F stretch
79		1238							C-O stretch
80				1221					C-O-C antisymmetric stretch
81			1220						C-O-C antisymmetric stretch
82		1209							O-H
83				1196					C-O/C-N stretch/C-F stretch
84				1173					C-O/C-N stretch/C-F stretch
85			1171						C-O
86						1157			C-F Stretch /C-O/C-N stretch
87								1156	C-F Stretch /C-O/C-N stretch
88	1155								C-F Stretch /C-O/C-N stretch

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
89							1136		C-O-C antisymmetric stretch
90					1132				C-O-C antisymmetric stretch
91		1128							C-O-C antisymmetric stretch
92						1115		1115	C-F Stretch /C-O/C-N stretch
93			1113						C=O
94				1102					C=O
95	1081								P=O stretching/C-F Stretch /C-O/C-N stretch
96								1079	P=O stretching/C-F Stretch /C-O/C-N stretch
97		1069							C-O stretching modes
98				1054					C-O stretching modes
99					1051		1051		C-O stretching modes

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
100						1049		1049	C-O stretching modes
101	1020				1020				C-O
102							994		C-O stretching modes
103		990							C-O stretching modes
104			964						C=O
105		942							C-C
106	929								CH=CH ₂ (CH ₂ out-of Plane wag)
107					927				CH=CH ₂ (CH ₂ out-of Plane wag)
108							926		CH=CH ₂ (CH ₂ out-of Plane wag)
109		910							CH=CH ₂
110			893						carbohydrate radical from the triglyceride structure
111						871			C-H(bend)

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
112		867							O-C-C
113				863				863	C-H(bend)/ N-H wag amines
114	860								C-H(bend)/ N-H wag amines
115							851		C-H(bend)/ N-H wag amines
116		849							CH=CH ₂
117					833				bending vibrations of C-H
118	764			764					C-C
119						763			C-C
120								762	C-C
121		731							C-O
122				722					(CH ₂) _n
123						721			(CH ₂) _n
124								720	(CH ₂) _n

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
125			719						(CH ₂) _n
126	707								C-H
127		683							O-C-C
128	669				669	669			C-Br/N-H wag amines
129							668		C-Br/N-H wag amines
130		642							Ring glucofuran
131				612					u4 mode of the phosphate group
132								609	u4 mode of the phosphate group
133				577				577	C-I
134	576								C-I
135		552							O-C-O

Table 4.8. Cont'd.

Sl. No.	Maida	Sugar	Shortening	Control bread	FDS powder	FDS bread	ODS powder	ODS bread	Assignment
136	529								C-I
137		471							O-C-C
138					467				Vibrations of PO4
139									Vibrations of PO4

4.3.7. Organoleptic evaluation of bread during storage

The sensory evaluation of control bread, bread incorporated with FDS powder and that incorporated with ODS powder were estimated during storage and the results are given in Table 4.9, Table 4.10 and Table 4.11.

The organoleptic quality of the control bread decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.77 ± 0.43 , 8.90 ± 0.31 , 8.80 ± 0.41 , 8.83 ± 0.38 , 8.80 ± 0.41 , 8.73 ± 0.45 , 8.80 ± 0.41 and 8.77 ± 0.43 , respectively on the 0th day to 6.83 ± 0.59 , 6.57 ± 0.50 , 6.07 ± 0.64 , 5.27 ± 0.87 , 5.10 ± 0.61 , 5.47 ± 0.82 , 5.13 ± 0.73 and 5.13 ± 0.82 , respectively on the 8th day. The organoleptic quality of the FDS bread decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.33 ± 0.48 , 8.37 ± 0.49 , 8.43 ± 0.50 , 8.57 ± 0.50 , 8.57 ± 0.50 , 8.43 ± 0.50 , 8.63 ± 0.49 and 8.47 ± 0.51 , respectively on the 0th day to 6.47 ± 0.63 , 6.20 ± 0.66 , 5.43 ± 0.77 , 4.70 ± 0.79 , 4.53 ± 0.51 , 4.70 ± 0.88 , 4.47 ± 0.51 and 4.47 ± 0.63 , respectively on the 8th day. The organoleptic quality of the ODS bread decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.13 ± 0.35 , 8.03 ± 0.49 , 8.57 ± 0.50 , 8.53 ± 0.51 , 8.43 ± 0.50 , 7.73 ± 0.64 , 8.50 ± 0.51 and 8.03 ± 0.61 , respectively on the 0th day to 6.57 ± 0.50 , 6.30 ± 0.70 , 5.47 ± 0.57 , 4.90 ± 0.84 , 4.60 ± 0.56 , 4.77 ± 0.90 , 4.53 ± 0.57 and 4.47 ± 0.63 , respectively on the 8th day.

Table 4.9. Organoleptic evaluation of control bread during storage

	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
Day 0	8.77 ± 0.43	8.90 ± 0.31	8.80 ± 0.41	8.83 ± 0.38	8.80 ± 0.41	8.73 ± 0.45	8.80 ± 0.41	8.77 ± 0.43
Day 2	8.30 ± 0.47	8.33 ± 0.48	8.23 ± 0.50	8.07 ± 0.69	7.77 ± 0.57	8.00 ± 0.64	8.00 ± 0.69	8.03 ± 0.72
Day 4	7.87 ± 0.43	7.77 ± 0.50	7.43 ± 0.50	7.37 ± 0.56	6.73 ± 0.52	6.80 ± 0.48	6.47 ± 0.51	6.67 ± 0.71
Day 6	7.63 ± 0.49	7.60 ± 0.50	6.67 ± 0.61	6.63 ± 0.67	6.57 ± 0.50	6.57 ± 0.57	6.03 ± 0.72	6.07 ± 0.83
Day 8	6.83 ± 0.59	6.57 ± 0.50	6.07 ± 0.64	5.27 ± 0.87	5.10 ± 0.61	5.47 ± 0.82	5.13 ± 0.73	5.13 ± 0.82

Table 4.10. Organoleptic evaluation of FDS bread during storage

	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
Day 0	8.33 ± 0.48	8.37 ± 0.49	8.43 ± 0.50	8.57 ± 0.50	8.57 ± 0.50	8.43 ± 0.50	8.63 ± 0.49	8.47 ± 0.51
Day 2	7.87 ± 0.35	8.03 ± 0.49	7.77 ± 0.50	7.83 ± 0.46	7.80 ± 0.55	7.90 ± 0.61	8.20 ± 0.66	8.10 ± 0.66
Day 4	7.63 ± 0.49	7.50 ± 0.51	6.93 ± 0.64	6.77 ± 0.43	6.53 ± 0.51	6.50 ± 0.51	6.00 ± 0.59	5.83 ± 0.83
Day 6	7.40 ± 0.50	7.23 ± 0.43	6.47 ± 0.57	6.37 ± 0.56	5.50 ± 0.51	5.43 ± 0.57	5.27 ± 0.58	5.20 ± 0.41
Day 8	6.47 ± 0.63	6.20 ± 0.66	5.43 ± 0.77	4.70 ± 0.79	4.53 ± 0.51	4.70 ± 0.88	4.47 ± 0.51	4.47 ± 0.63

Table 4.11. Organoleptic evaluation of ODS bread during storage

	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
Day 0	8.13 ± 0.35	8.03 ± 0.49	8.57 ± 0.50	8.53 ± 0.51	8.43 ± 0.50	7.73 ± 0.64	8.50 ± 0.51	8.03 ± 0.61
Day 2	7.90 ± 0.40	7.80 ± 0.48	7.73 ± 0.45	7.97 ± 0.56	7.80 ± 0.61	6.77 ± 0.43	7.57 ± 0.57	7.60 ± 0.50
Day 4	7.63 ± 0.49	7.60 ± 0.50	6.93 ± 0.58	6.83 ± 0.59	6.67 ± 0.48	6.60 ± 0.56	6.20 ± 0.61	6.20 ± 0.85
Day 6	7.37 ± 0.56	7.13 ± 0.63	6.43 ± 0.50	6.47 ± 0.57	5.67 ± 0.48	5.50 ± 0.63	5.43 ± 0.50	5.37 ± 0.56
Day 8	6.57 ± 0.50	6.30 ± 0.70	5.47 ± 0.57	4.90 ± 0.84	4.60 ± 0.56	4.77 ± 0.90	4.53 ± 0.57	4.47 ± 0.63

4.3.8. Amino acid composition of bread

The amino acid content of bread incorporated with FDS powder and that incorporated with ODS powder were analysed and the results are given in Table 4.12.

4.12. Amino acid content of bread

EAAs	Control bread (g/100 g)	ODS bread (g/100 g)	FDS bread (g/100 g)
Lysine	0.12	0.23	0.28
Therionine	0.16	0.39	0.32
Valine	0.12	0.58	0.56
Methionine	0.04	0.18	0.12
Isolucine	0.08	0.24	0.24
Phenylalanine	0.14	0.26	0.28
Histidine	0.06	0.14	0.18
Tyrosine	0.08	0.14	0.12
Cysteine	0.04	0.08	0.06
Leucine	0.32	0.82	0.78
Total EAAs	1.16	3.06	2.94
NEAA			
Aspartic acid	0.23	0.38	0.42
Glutamic acid	0.68	1.18	1.16
Arginine	0.12	0.29	0.26
Serine	0.18	0.68	0.72

Table 4.12. cont'd

EAAAs	Control bread (g/100 g)	ODS bread (g/100 g)	FDS bread (g/100 g)
Proline	0.19	0.21	0.22
Glycine	0.06	0.38	0.31
Alanine	0.08	0.26	0.22
Total NEAAs	1.54	3.38	3.31
Total AM	2.70	6.44	6.25

The amino acid content of bread increased when surimi powder was incorporated.

4.3.9 Minerals in bread

The mineral content in bread were analysed and the results are given in Table 4.13.

Table 4.13. Minerals in bread

Mineral	Control bread (10⁻² g/kg)	ODS Bread (10⁻² g/kg)	FDS Bread (10⁻² g/kg)
Phosphorus	65 ± 7	72 ± 7	78 ± 11
Calcium	2.5 ± 0.5	7.2 ± 0.2	8.4 ± 0.8
Zinc	1.7 ± 0.1	1.8 ± 0.1	2.1 ± 0.4
Iron	5.1 ± 0.2	5.4 ± 0.2	5.7 ± 0.1

The phosphorus, calcium, zinc and iron content were $(65 \pm 7) \times 10^{-2}$ g/kg, $(2.5 \pm 0.5) \times 10^{-2}$ g/kg, $(1.7 \pm 0.1) \times 10^{-2}$ g/kg and $(5.1 \pm 0.2) \times 10^{-2}$ g/kg, respectively in control bread, $(72 \pm 7) \times 10^{-2}$ g/kg, $(7.2 \pm 0.2) \times 10^{-2}$ g/kg, $(1.8 \pm 0.1) \times 10^{-2}$ g/kg and $(5.4 \pm 0.2) \times 10^{-2}$ g/kg, respectively in ODS bread and $(78 \pm 11) \times 10^{-2}$ g/kg, $(8.4 \pm 0.8) \times 10^{-2}$ g/kg, $(2.1 \pm 0.4) \times 10^{-2}$ g/kg and $(5.7 \pm 0.1) \times 10^{-2}$ g/kg, respectively.

4.4. Cake

Cakes were prepared by incorporating different proportions of FDS and ODS powder and their various characteristics were evaluated.

4.4.1 Proximate composition of cake with surimi powder

The proximate composition of cake incorporated with FDS powder and that incorporated with ODS powder were estimated and the results are given in Fig. 4.40 and Fig. 4.41, respectively.

The moisture, ash, fat, protein and carbohydrates contents in control cake, cake incorporated with 10%, 20% and 30% FDS powder were $22.46 \pm 0.56\%$, $0.37 \pm 0.06\%$, $28.49 \pm 0.10\%$, $6.11 \pm 0.05\%$ and 42.58 ± 0.64 , respectively, $22.13 \pm 0.15\%$, $0.80 \pm 0.10\%$, $28.82 \pm 0.16\%$, $8.13 \pm 0.06\%$ and $40.12 \pm 0.32\%$, respectively, $24.84 \pm 0.84\%$, $1.06 \pm 0.06\%$, $29.14 \pm 0.12\%$, $10.08 \pm 0.20\%$ and $34.87 \pm 0.73\%$, respectively, and $27.03 \pm 1.51\%$, $1.20 \pm 0.00\%$, $29.83 \pm 0.26\%$, $12.09 \pm 0.22\%$ and $29.85 \pm 1.37\%$, respectively.

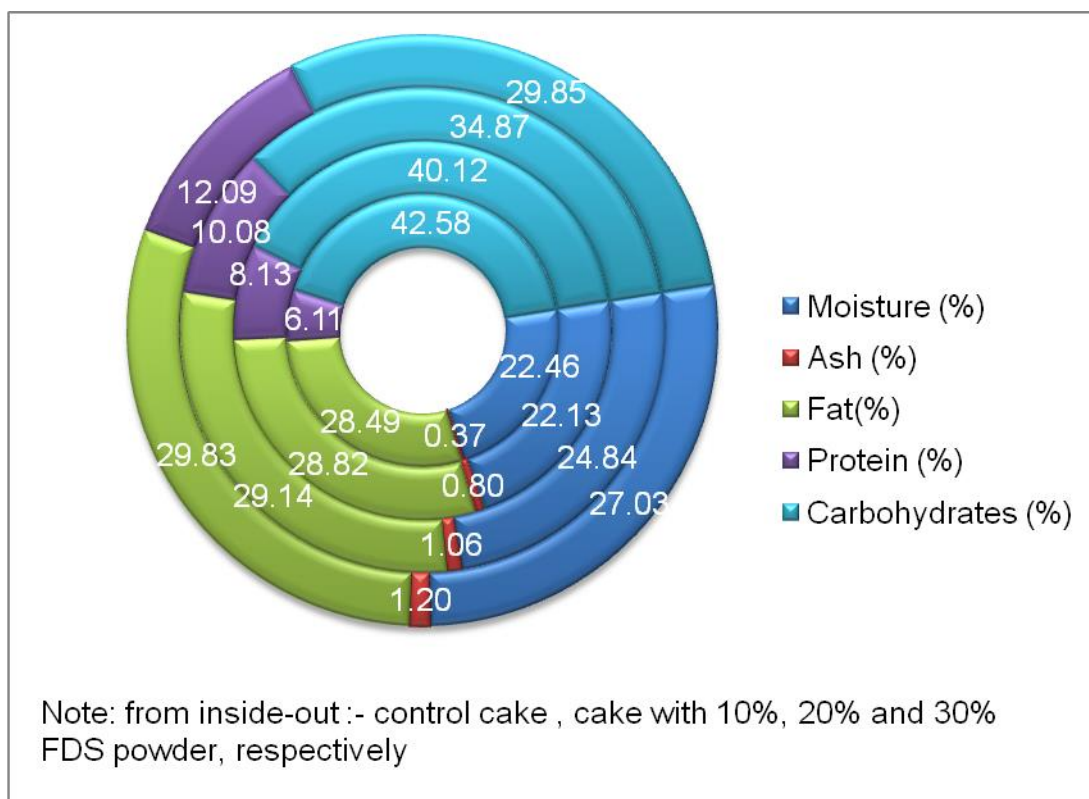


Fig. 4.40. Proximate composition of cake with FDS powder

The moisture , ash, fat, protein and carbohydrates contents in control cake, cake incorporated with 10%, 20% and 30% ODS powder were $22.46 \pm 0.56\%$, $0.37 \pm 0.06\%$, $28.49 \pm 0.10\%$, $6.11 \pm 0.05\%$ and $42.58 \pm 0.64\%$, respectively, $22.53 \pm 0.11\%$, $0.80 \pm 0.10\%$, $28.21 \pm 0.06\%$, $8.03 \pm 0.03\%$ and $40.44 \pm 0.19\%$, respectively, $24.96 \pm 0.37\%$, $1.06 \pm 0.15\%$, $28.92 \pm 0.12\%$, $10.08 \pm 0.18\%$, and $34.97 \pm 0.55\%$, respectively, and $26.79 \pm 0.33\%$, $1.23 \pm 0.06\%$, $29.73 \pm 0.57\%$, $11.92 \pm 0.22\%$ and $30.32 \pm 0.04\%$, respectively.

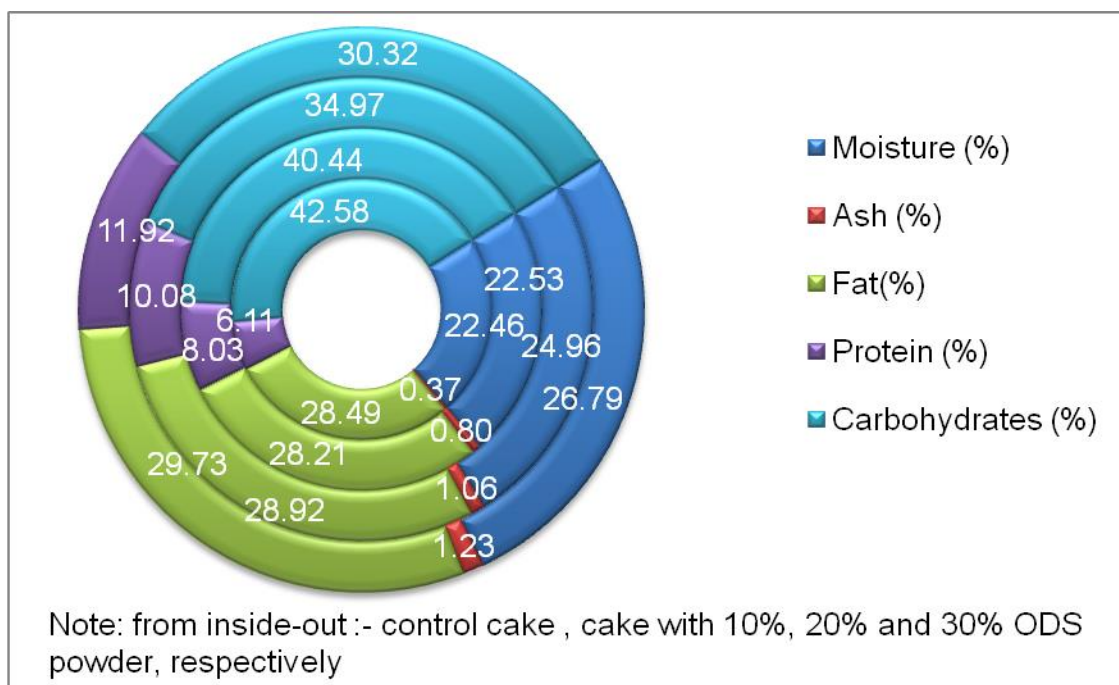


Fig. 4.41. Proximate composition of cake with ODS powder

4.4.2 Sensory evaluation of cakes incorporated with surimi powder

The sensory evaluation of cakes incorporated with FDS powder and that incorporated with ODS powder were evaluated and the results are given in Fig. 4.42. and Fig. 4.43., respectively.

The sensory scores on an average for control cake, cake incorporated with 10%, 20% and 30% FDS powder were 8.87 ± 0.35 , 8.60 ± 0.50 , 8.60 ± 0.50 and 8.23 ± 0.63 , respectively for the attribute appearance, 8.93 ± 0.25 , 8.67 ± 0.48 , 8.57 ± 0.50 and 8.47 ± 0.57 , respectively for the attribute colour, 8.83 ± 0.38 , 8.57 ± 0.50 , 7.43 ± 0.50 and 4.83 ± 0.83 respectively for the attribute odour, respectively, 8.87 ± 0.35 , 8.63 ± 0.49 , 7.43 ± 0.50 and 3.73 ± 0.45 for the attribute taste, 8.83 ± 0.38 , 8.63 ± 0.49 , 7.40 ± 0.50 and 3.63 ± 0.49 , respectively for the attribute mouth

feel, 8.77 ± 0.43 , 8.53 ± 0.51 , 6.83 ± 0.46 and 3.60 ± 0.50 , respectively for the attribute flavour, 8.83 ± 0.38 , 8.77 ± 0.43 , 7.03 ± 0.49 and 4.83 ± 0.53 , respectively for the attribute texture and 8.87 ± 0.35 , 8.60 ± 0.50 , 6.83 ± 0.46 and 3.77 ± 0.43 , respectively for overall acceptability.

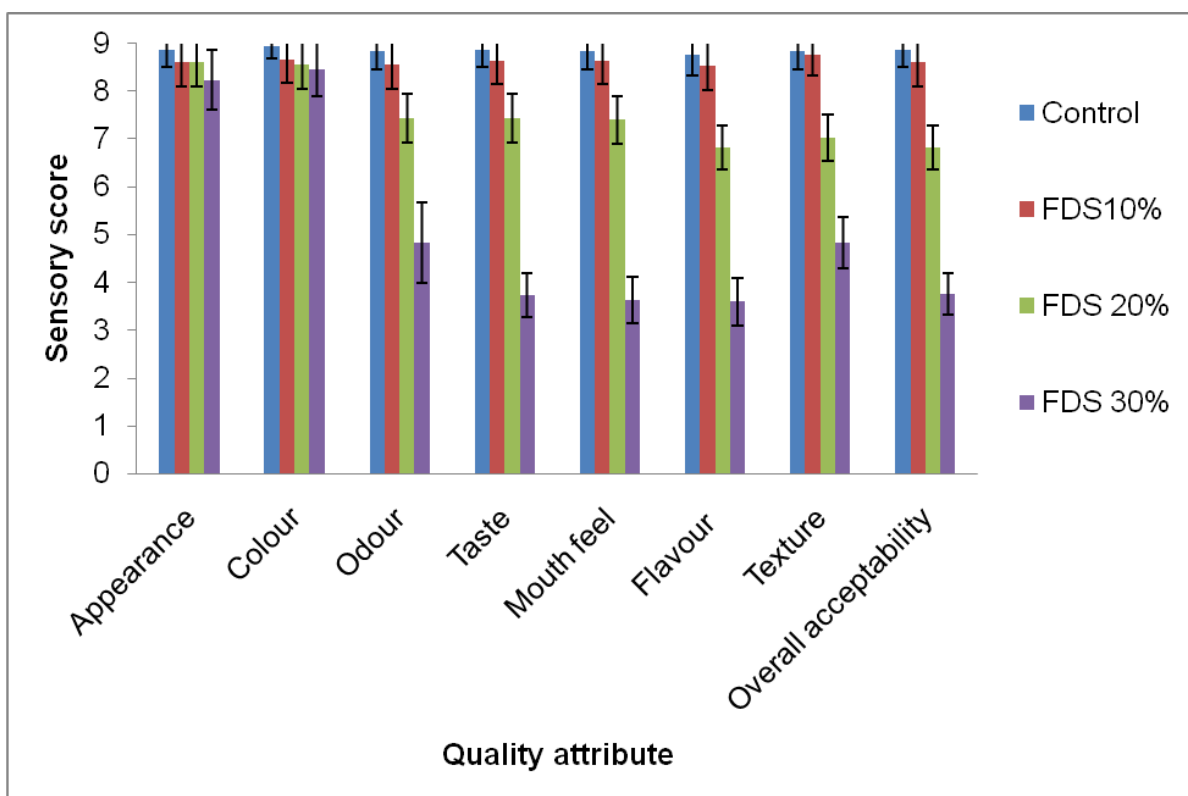


Fig. 4.42. Sensory scores of cakes incorporated with FDS powder

The sensory scores on an average for control cake, cake incorporated with 10%, 20% and 30% ODS powder were 8.87 ± 0.35 , 8.73 ± 0.45 , 8.47 ± 0.51 and 8.13 ± 0.63 , respectively for the attribute appearance, 8.93 ± 0.25 , 8.83 ± 0.38 , 8.50 ± 0.51 and 8.33 ± 0.66 , respectively for the attribute colour, 8.83 ± 0.38 , 8.67 ± 0.48 , 7.37 ± 0.49 and 4.73 ± 0.87 , respectively for the attribute odour, 8.87 ± 0.35 , 8.67 ± 0.48 , 7.33 ± 0.48 and 3.63 ± 0.49 , respectively, for the attribute taste,

8.83 $\pm$ 0.38, 8.67 $\pm$ 0.48, 7.33 $\pm$ 0.48 and 3.53 $\pm$ 0.51, respectively for the attribute mouth feel, 8.77 $\pm$ 0.43, 8.60 $\pm$ 0.50, 6.77 $\pm$ 0.50 and 3.50 $\pm$ 0.51, respectively for the attribute flavour, 8.83 $\pm$ 0.38, 8.77 $\pm$ 0.43, 6.90 $\pm$ 0.48 and 4.73 $\pm$ 0.58, respectively for the attribute texture and, 8.87 $\pm$ 0.35, 8.63 $\pm$ 0.49, 6.73 $\pm$ 0.45 and 3.63 $\pm$ 0.49 respectively for overall acceptability.

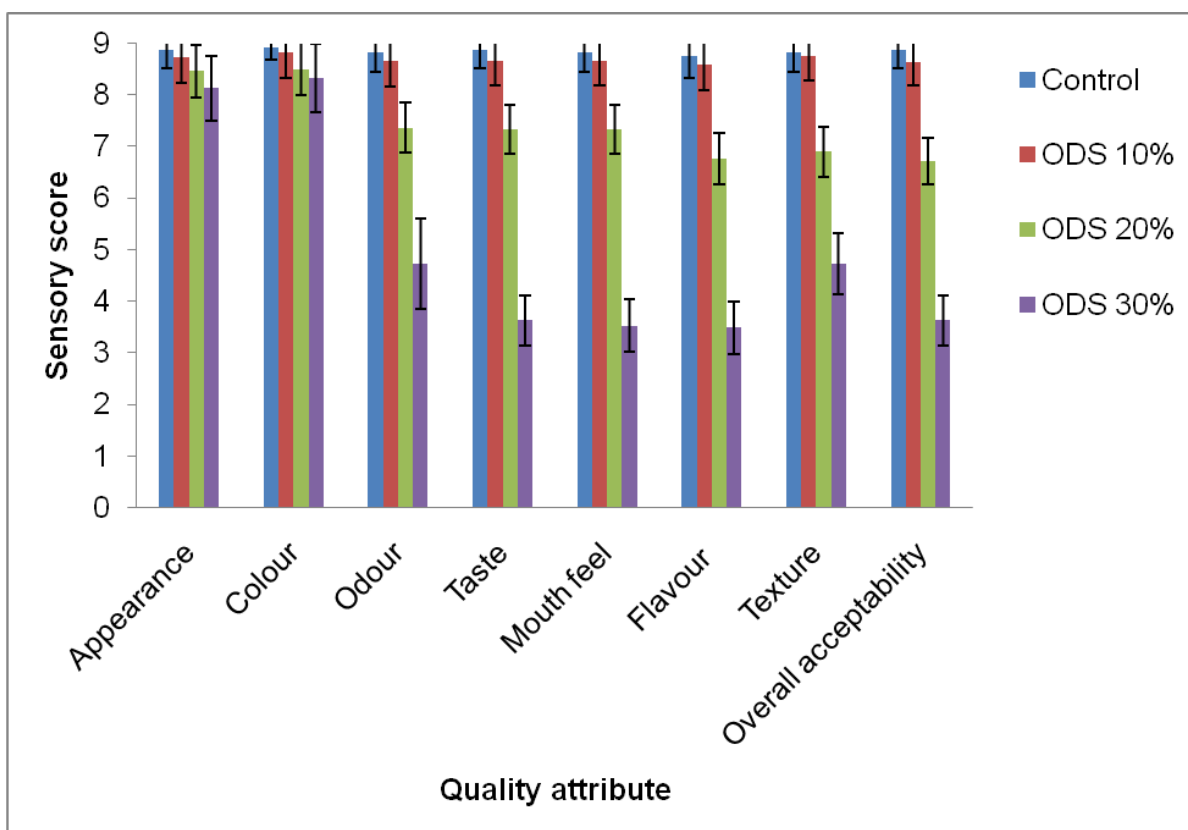


Fig. 4.43. Sensory scores of cakes incorporated with ODS powder

Plate III. Cakes incorporated with surimi powder



Control cake



FDS Cake



ODS cake

4.4.3 Microstructure of cake

Scanning electron microscopic images of control cake, cake incorporated with 10% FDS powder and that incorporated with 10% ODS powder were observed and the images are given in Fig. 4.44, Fig. 4.45 and Fig. 4.46, respectively.

Large numbers of pores were present in all the cakes. FDS cakes had higher number of micro-pores than control and ODS cakes. Evenness in structure was higher in control cake than FDS and ODS cakes.

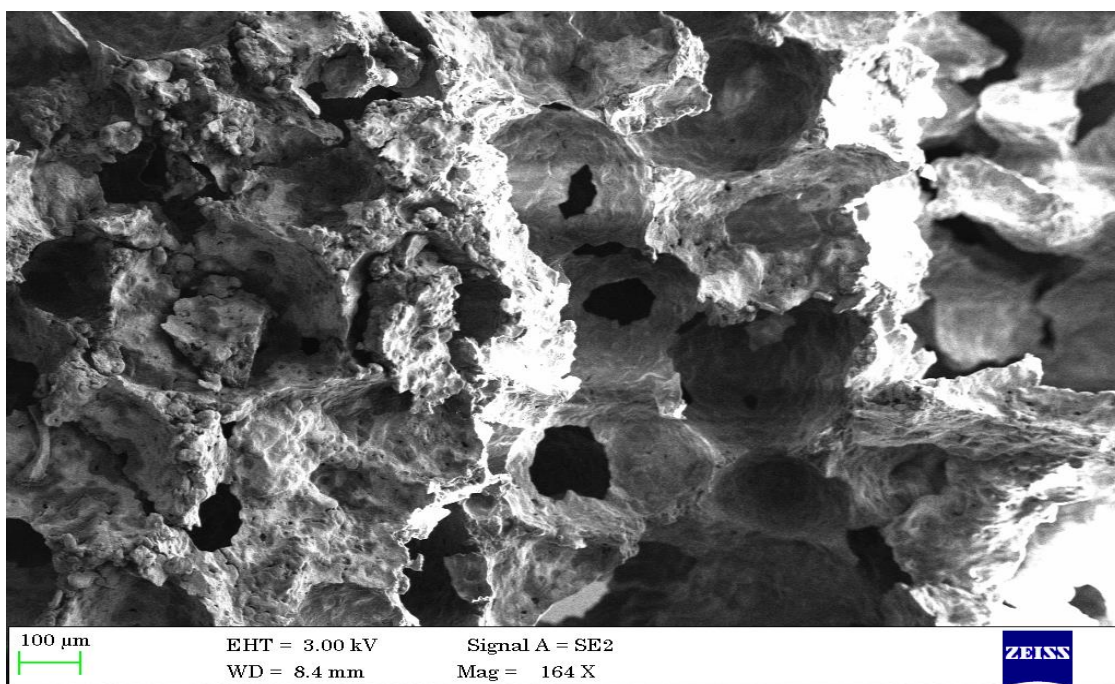


Fig. 4.44. SEM image of control cake

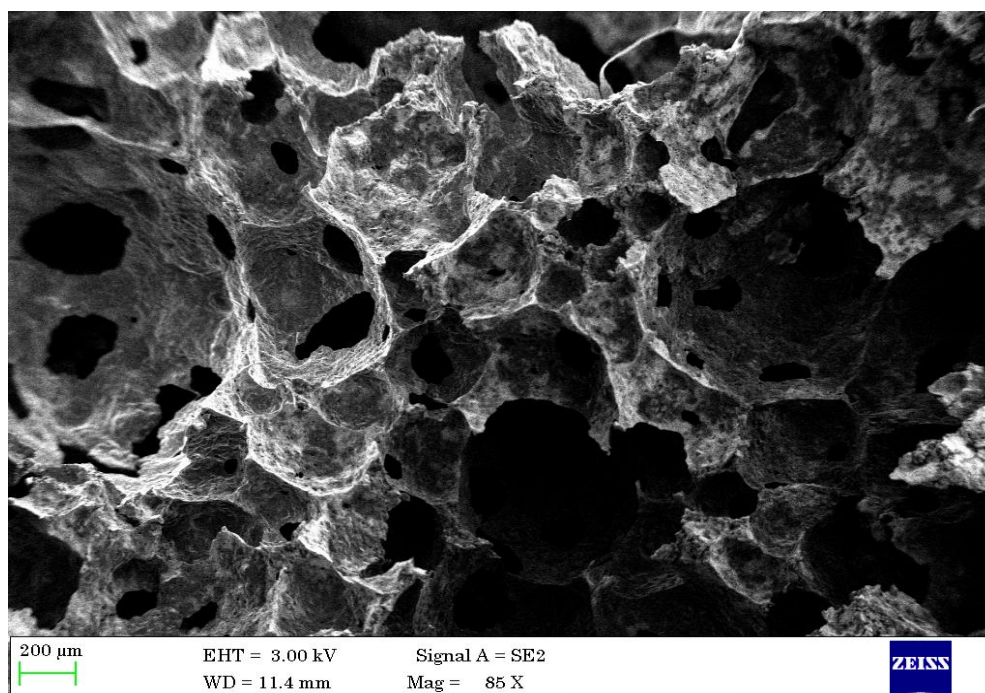


Fig. 4.45. SEM image of FDS cake

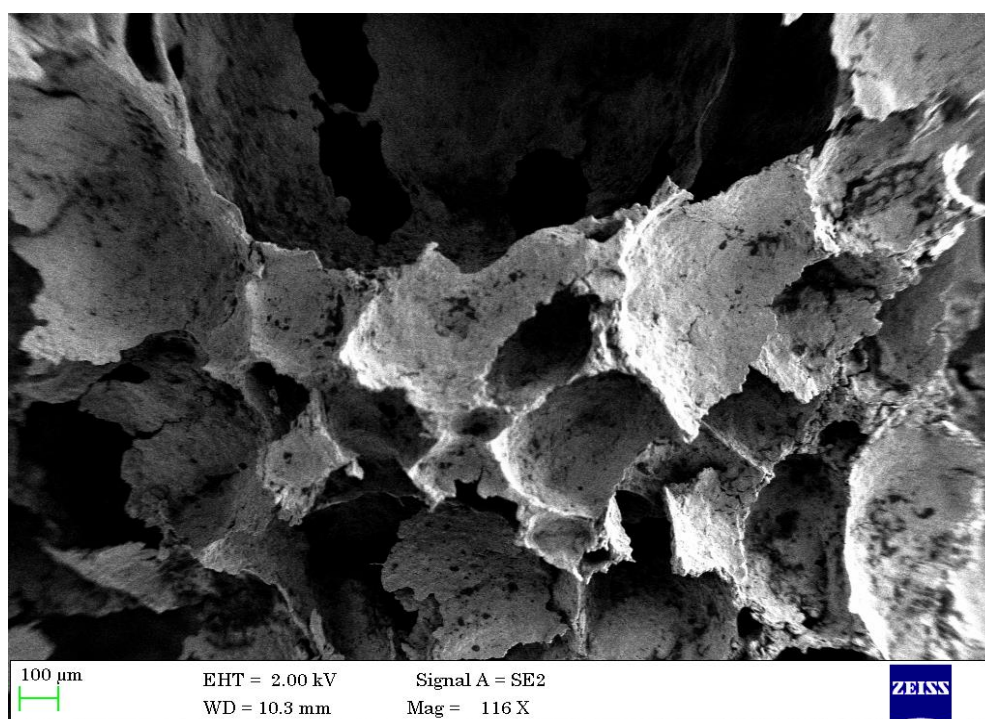


Fig. 4.46. SEM image of ODS cake

4.4.4 Storage stability of cakes incorporated with surimi powder

4.4.4.1 TBARS value of cakes incorporated with surimi powder during storage

The TBARS values of cakes incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.47.

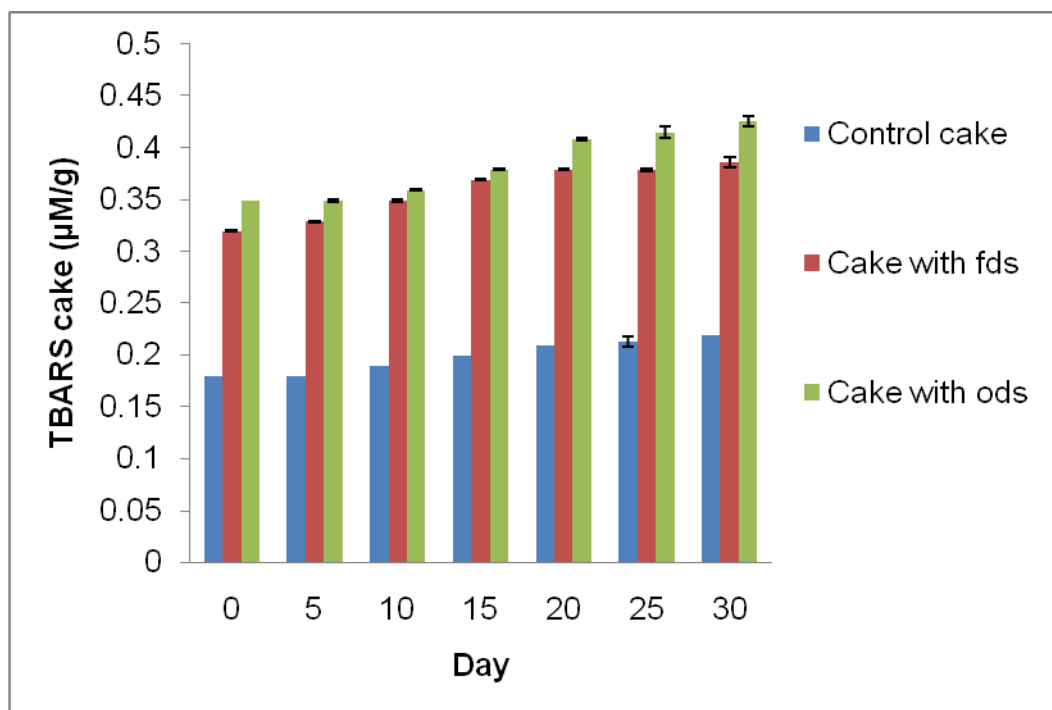


Fig. 4.47. TBARS value of cakes during storage

The TBARS values of control cake, cake incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.18 μM/g, 0.32 μM/g and 0.35 μM/g, respectively, which gradually increased to 0.22 μM/g, 0.39 μM/g and 0.43 μM/g, respectively by 30th day.

4.4.4.2 Peroxide value of cakes incorporated with surimi powder during storage

The peroxide values of cakes incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.48.

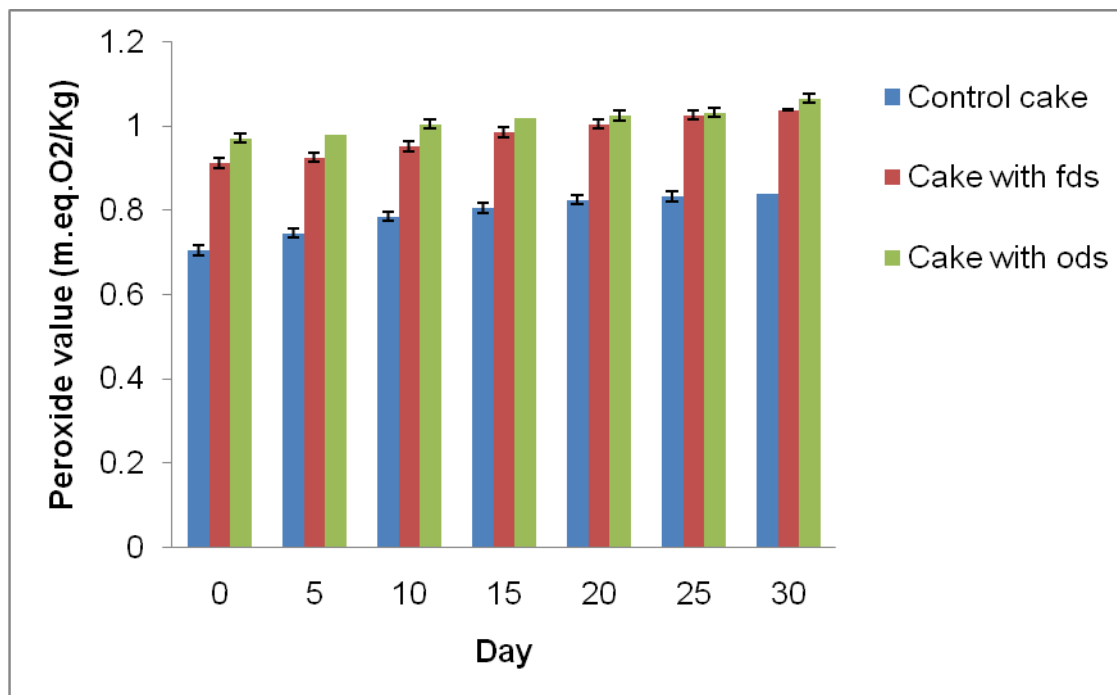


Fig. 4.48. Peroxide value of cakes during storage

The peroxide values of control cake, cake incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.71 ± 0.01 m.eq.O₂/Kg, 0.91 ± 0.01 m.eq.O₂/Kg and 0.97 ± 0.01 m.eq.O₂/Kg, respectively, which gradually increased to 0.84 ± 0.00 m.eq.O₂/Kg, 1.04 ± 0.00 m.eq.O₂/Kg and 1.07 ± 0.01 m.eq.O₂/Kg, respectively by the 30th day.

4.4.4.3 Free fatty acid in cakes incorporated with surimi powder during storage

The free fatty acid in cakes incorporated with FDS and ODS surimi powder were evaluated and the results are given in Fig. 4.49.

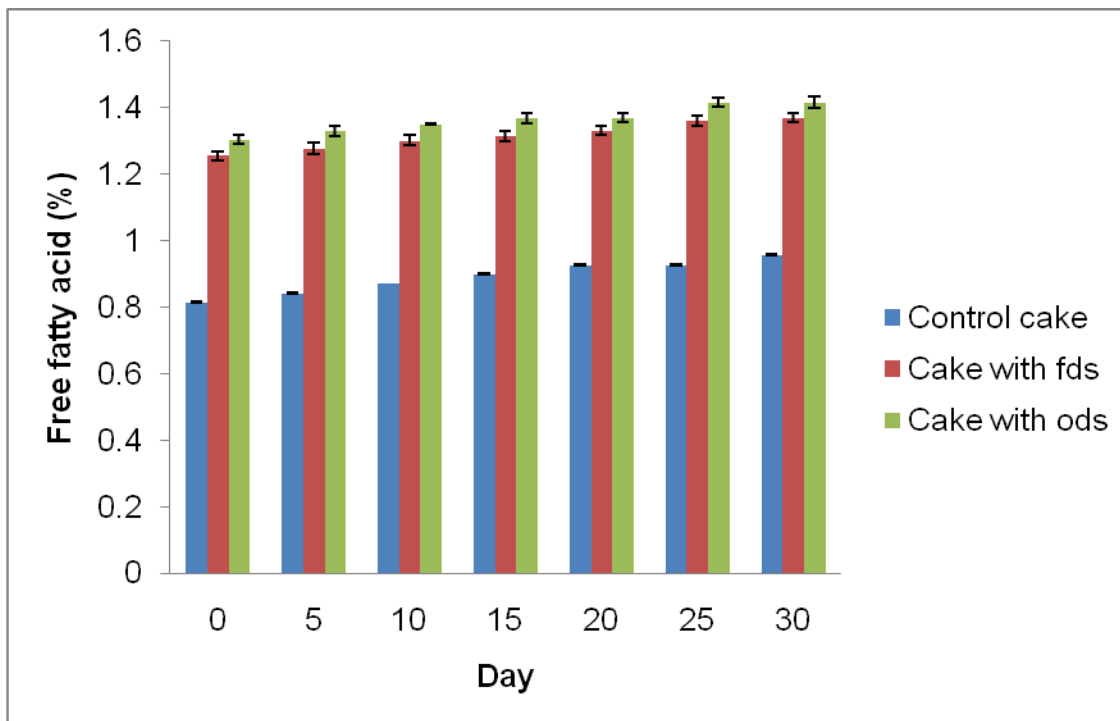


Fig. 4.49. Free fatty acid in cakes during storage

The free fatty acids in control cake, cake incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.82 \pm 0.00\%$, $1.26 \pm 0.01\%$ and $1.30 \pm 0.01\%$, respectively, which gradually increased to $0.96 \pm 0.00\%$, $1.37 \pm 0.01\%$ and $1.42 \pm 0.02\%$, respectively by the 30th day.

4.4.5 Microbial quality of cakes during storage

The total plate count of control cakes, cakes incorporated with FDS powder and that incorporated with ODS powder were estimated and the results are given in Fig. 4.50.

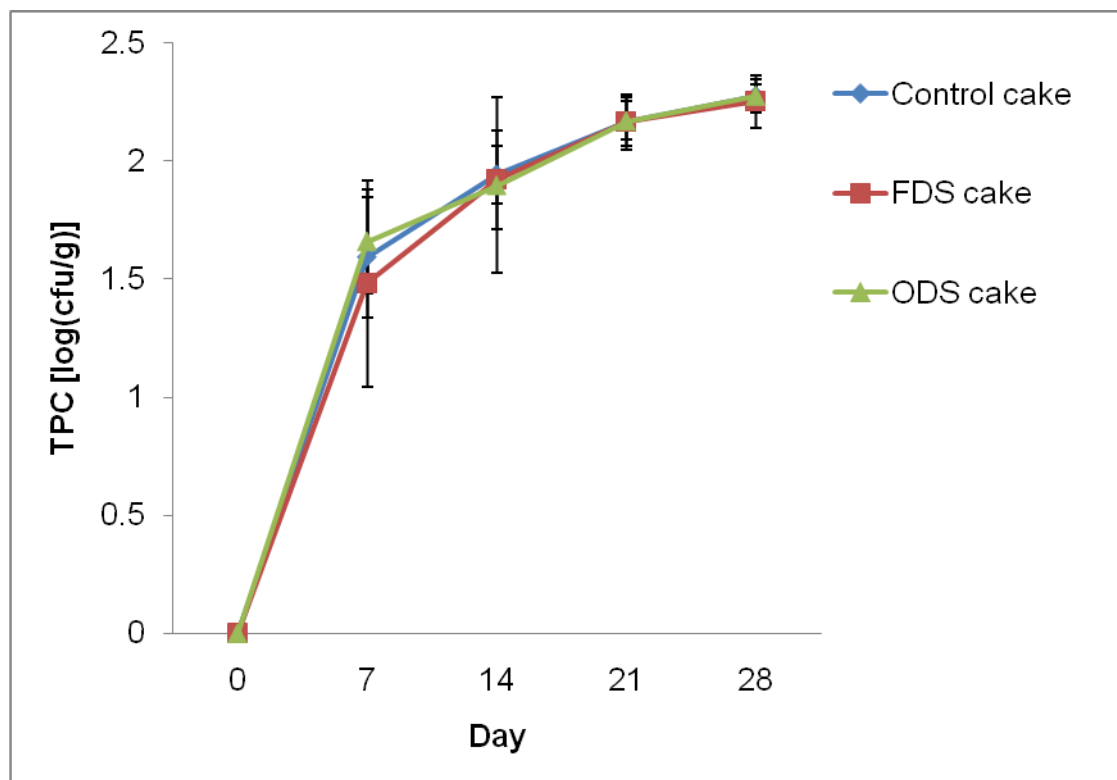


Fig. 4.50. Total plate count of cakes.

The total plate count of control cake, cake incorporated with FDS powder and that incorporated with ODS powder were not detected on the 0th day and were 1.59 ± 0.26 logcfu/g, 1.48 ± 0.44 logcfu/g and 1.66 ± 0.22 logcfu/g on the 7th day and then increased to 2.28 ± 0.07 logcfu/g, 2.25 ± 0.11 logcfu/g and 2.28 ± 0.05 logcfu/g, respectively on the 28th day. Total fungal count was not detected in any of cakes.

4.4.6 Fourier Transform Infrared Spectroscopy of cakes

FTIR spectrum was analysed to examine the functional interaction that took place during the formulation and processing of cakes. The FTIR Spectra were collected in the transmission mode using FTIR Spectrometer for the different ingredients *viz.* cocoa powder, oil, maida, sugar, FDS powder and ODS powder, and also the final products *viz.* control cake, cakes incorporated with FDS powder and that incorporated with ODS powder and are given in Fig. 4.17 to Fig. 4.19, Fig. 4.21, Fig. 4.22 and Fig 4.51 to Fig. 4.54. and the assignments of peak are given in Table 4.14.

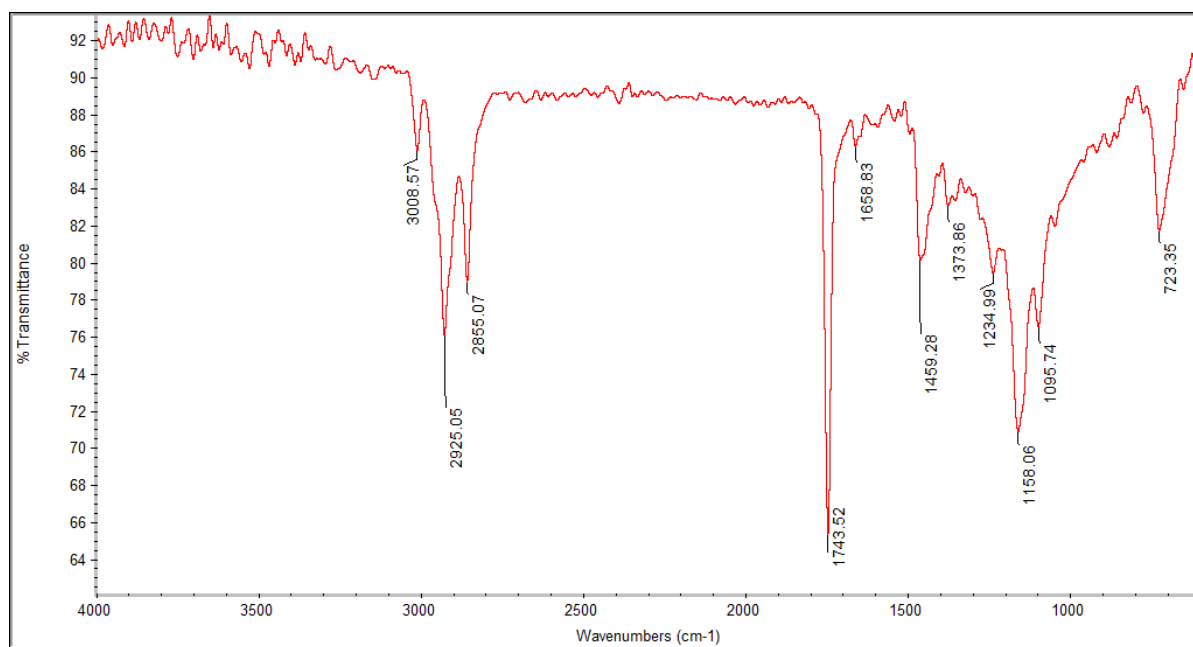


Fig. 4.51. FTIR analysis of refined sunflower oil

The FTIR peaks at 3009 cm^{-1} , 2925 cm^{-1} , 2855 cm^{-1} , 1744 cm^{-1} , 1659 cm^{-1} , 1459 cm^{-1} , 1374 cm^{-1} , 1235 cm^{-1} , 1158 cm^{-1} , 1096 cm^{-1} and 723 cm^{-1} were obtained for oil for which the probable assignments are C-H expansion vibration - unsaturated

oil/linoleic acid, C-H, C-H (symmetric), C=O stretching vibration (high content in saturated fatty acids and short carbohydrate chain), C=C, CH₂ bending modes, CH₂ bending modes, C-O, C-O, C=O and (CH₂)_n, respectively .

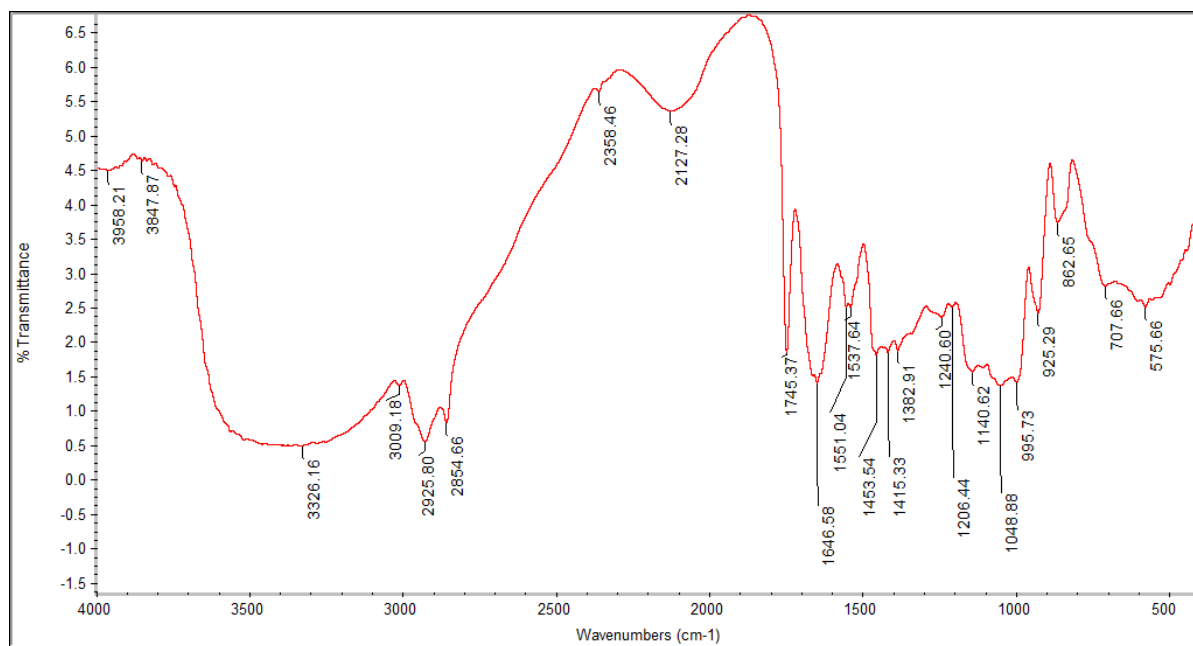


Fig. 4.52. FTIR analysis of control cake

The FTIR peaks at 3009 cm⁻¹, 2926 cm⁻¹, 2855 cm⁻¹, 2358 cm⁻¹, 2127 cm⁻¹, 1745 cm⁻¹, 1647 cm⁻¹, 1551 cm⁻¹, 1538 cm⁻¹, 1454 cm⁻¹, 1415 cm⁻¹, 1383 cm⁻¹, 1241 cm⁻¹, 1206 cm⁻¹, 1141 cm⁻¹, 1049 cm⁻¹, 996 cm⁻¹, 863cm⁻¹, 708 cm⁻¹ and 576 cm⁻¹ were obtained for control cake for which the probable assignments are C - H expansion vibration - unsaturated oil/linoleic acid, C-H/N-H, C-H (symmetric), N=H, intra-molecular O-H hydrogen bonds, C-H stretching/C=O/ Asp-95, C=C/N=H, N-H, N-H stretching vibrations, C=C in-plane vibration, C-O stretching and OH deformation of the carboxyl group, C-H bending, C-O/C-F stretch, C-O/C-N stretch/C-F stretch, C-O-C antisymmetric stretch, C-O stretching modes, C-O stretching modes, C-H(bend)/ N-H wag amines, C-H and C-I, respectively.

Unidentified peaks were obtained at 3958 cm^{-1} , 3848 cm^{-1} and 3326 cm^{-1} for control cake.

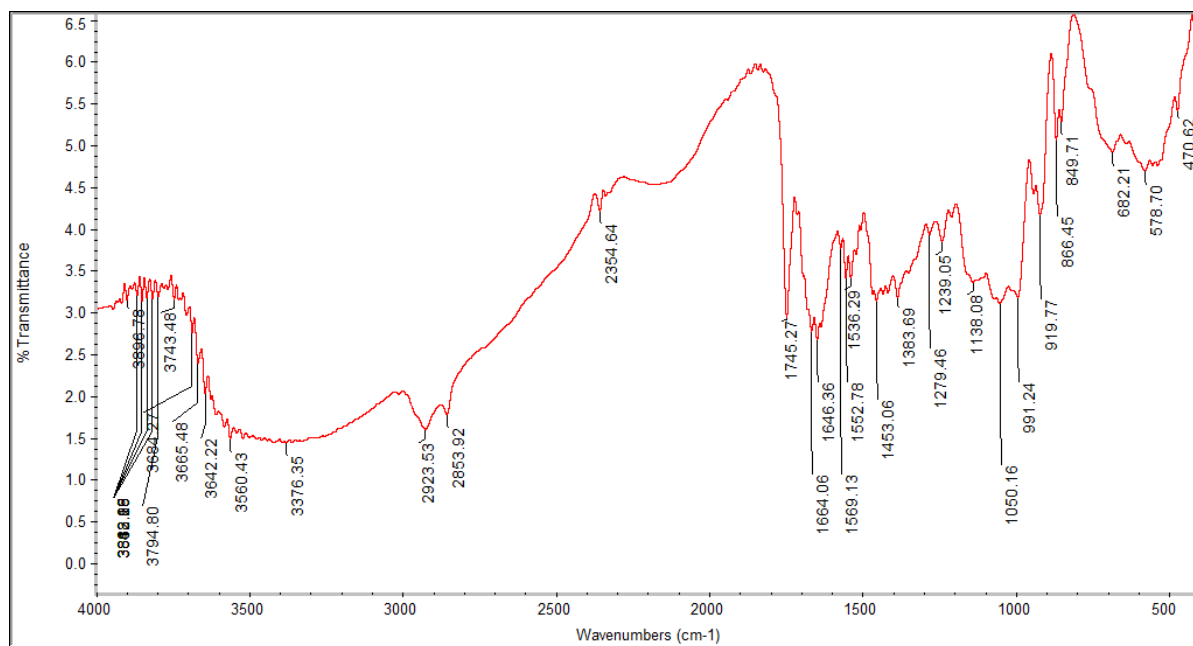


Fig. 4.53. FTIR analysis of FDS cake

The FTIR peaks at 3560 cm^{-1} , 3376 cm^{-1} , 2924 cm^{-1} , 2854 cm^{-1} , 2355 cm^{-1} , 1745 cm^{-1} , 1646 cm^{-1} , 1553 cm^{-1} , 1536 cm^{-1} , 1453 cm^{-1} , 1384 cm^{-1} , 1279 cm^{-1} , 1239 cm^{-1} , 1138 cm^{-1} , 1050 cm^{-1} , 991 cm^{-1} , 920 cm^{-1} , 866 cm^{-1} , 850 cm^{-1} , 682 cm^{-1} , 579 cm^{-1} and 471 cm^{-1} were obtained for FDS cake for which the probable assignments are O-H, O-H, C-H/N-H, C-H (symmetric)/N-H, C-O, C-H stretching/C=O/ Asp-95, C=C/N=H, N-H, N-H stretching vibrations, C=C in-plane vibration, C-H bending, C-H, C-O/C-F stretch, C-O-C antisymmetric stretch, C-O stretching modes, C-O stretching modes, CH=CH₂ (CH₂ out-of Plane wag), C-H(bend)/ N-H wag amines, C-H(bend)/ N-H wag amines, O-C-C, C-I and O-C-C respectively. Unidentified peaks were obtained at 3896 cm^{-1} , 3795 cm^{-1} , 3743 cm^{-1} , 3684 cm^{-1} , 3665 cm^{-1} and 3642 cm^{-1} for FDS cake.

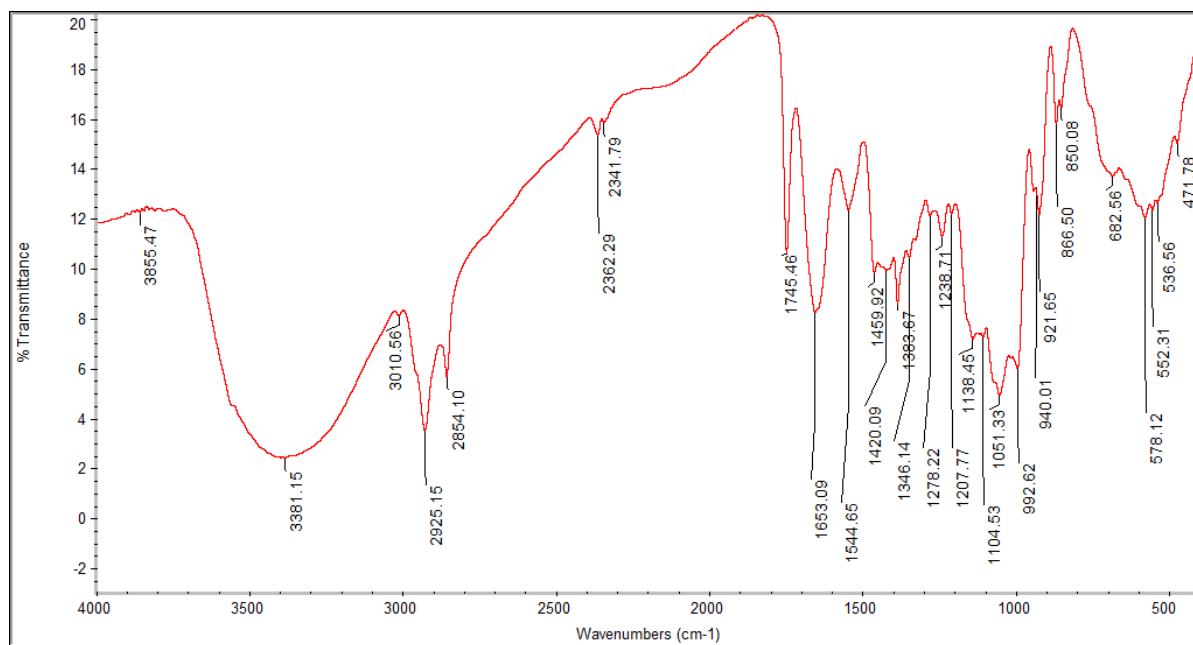


Fig. 4.54. FTIR analysis of ODS cake

The FTIR peaks at 3381 cm^{-1} , 3011 cm^{-1} , 2925 cm^{-1} , 2854 cm^{-1} , 2362 cm^{-1} , 2342 cm^{-1} , 1745 cm^{-1} , 1653 cm^{-1} , 1545 cm^{-1} , 1420 cm^{-1} , 1384 cm^{-1} , 1278 cm^{-1} , 1239 cm^{-1} , 1208 cm^{-1} , 1138 cm^{-1} , 1105 cm^{-1} , 1051 cm^{-1} , 993 cm^{-1} , 940 cm^{-1} , 922 cm^{-1} , 867 cm^{-1} , 683 cm^{-1} , 578 cm^{-1} , 552 cm^{-1} , 537 cm^{-1} and 471 cm^{-1} were obtained for ODS cake for which the probable assignments are O-H, C - H expansion vibration - unsaturated oil/linoleic acid, C-H, C-H (symmetric)/N-H, N=H, C-O vibration, C-H stretching/C=O/ Asp-95, C=C/N-H in plane bend, N-H out of plane, C-O stretching and OH deformation of the carboxyl group, C-H bending, C-H, C-O/C-F stretch, C-O/C-N stretch/C-F stretch, C-O-C antisymmetric stretch, C=O, C-O stretching modes, C-C, CH=CH₂ (CH₂ out-of Plane wag), O-C-C, C-H(bend)/ N-H wag amines, O-C-C, C-I, O-C-O, C-I and O-C-C respectively. Unidentified peak was obtained at 3855 cm^{-1} for ODS cake.

Table 4. 14. Assignment of FTIR Peaks – Ingredients and cakes

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	Assignment
1					3958					
2							3896			
3			3891							
4									3855	
5					3848					
6						3841				
7								3832		
8								3813		
9	3809									
10			3808							
11	3788						3795			
12			3772							

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
13						3753				
14							3743			
15							3684			
16	3680									
17							3665			
18	3657							2362		
19							3642			
20				3562						O-H
21							3560			O-H
22						3414				O-H
23	3410									O-H
24			3397							O-H

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
25				3389						O-H
26								3386		O-H
27									3381	O-H
28							3376			O-H
29					3326					O-H
30				3014						C-H (stretch)
31									3011	C - H expansion vibration - unsaturated oil/linoleic acid
32		3009			3009					C - H expansion vibration - unsaturated oil/linoleic acid
33				2971						C-H
34				2940						C-H

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
35			2928							C-H/N-H
36					2926	2926		2926		C-H/N-H
37		2925							2925	C-H
38	2924						2924			C-H/N-H
39				2913						intra-molecular O–H hydrogen bonds
40		2855			2855					C-H (symmetric)
41							2854		2854	C-H (symmetric)/N-H
42	2853									C-H (symmetric)/N-H
43				2724						intra-molecular O–H hydrogen bonds
44						2364				N=H
45				2363						intra-molecular O–H hydrogen bonds
46								2362	2362	N=H

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
47	2361		2361							N=H
48					2358					N=H
49							2355			C-O
50									2342	C-O vibration
51	2341		2341							C-O vibration
52					2127					intra-molecular O–H hydrogen bonds
53				2126						intra-molecular O–H hydrogen bonds
54	1745				1745		1745		1745	C-H stretching/C=O/ Asp-95
55		1744								C = O stretching vibration - high content in saturated fatty acids and short carbohydrate chain
56		1659								C=C

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
57			1657							C=C/N-H in plane blend
58						1655				C=C/N-H in plane blend
59									1653	C=C/N-H in plane blend
60					1647			1647		C=C/N=H
61							1646			C=C/N=H
62							1553	1553		N-H
63					1551					N-H
64			1548							N-H out of plane
65						1546				N-H out of plane
66									1545	N-H out of plane
67					1538					N-H stretching vibrations
68								1537		N-H stretching vibrations

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
69							1536			N-H stretching vibrations
70	1531									N-H
71				1461						CH ₂ scissoring modes
72		1459								CH ₂ bending modes
73					1454					C=C in-plane vibration
74							1453	1453		C=C in-plane vibration
75						1447				C–O stretching vibration
76	1443									in-plane mode of N–H
77				1431						C-H
78			1425							C-O stretching and OH deformation of the carboxyl group

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
79									1420	C-O stretching and OH deformation of the carboxyl group
80					1415					C-O stretching and OH deformation of the carboxyl group
81						1403				C-H bending
82							1384		1384	C-H bending
83	1383				1383					C-H bending
84			1382							C-H bending
85		1374								CH ₂ bending modes
86				1369						C-H
87				1346						O-H
88				1323						C-H

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
89							1279			C-H
90									1278	C-H
91	1252									C-F Stretch
92			1243							C-O
93					1241					C-O/C-F stretch
94							1239		1239	C-O/C-F stretch
95				1238						C-O stretch
96		1235								C-O
97				1209						O-H
98					1206					C-O/C-N stretch/C-F stretch
99		1158								C-O
100	1157									C-F Stretch /C-O/C-N stretch

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
101			1155							C-F Stretch /C-O/C-N stretch
102					1141					C-O-C antisymmetric stretch
103							1138		1138	C-O-C antisymmetric stretch
104								1136		C-O-C antisymmetric stretch
105						1132				C-O-C antisymmetric stretch
106				1128						C-O-C antisymmetric stretch
107									1105	C=O
108		1096								C=O
109			1081							P=O stretching/C-F Stretch /C-O/C-N stretch
110				1069						C-O stretching modes
111						1051		1051	1051	C-O stretching modes

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
112							1050			C-O stretching modes
113					1049					C-O stretching modes
114	1022									C-O
115			1020			1020				C-O
116					996					C-O stretching modes
117								994		C-O stretching modes
118									993	C-O stretching modes
119							991			C-O stretching modes
120				990						C-O stretching modes
121				942						C-C
122									940	C-C
123			929							CH=CH ₂ (CH ₂ out-of Plane wag)

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
124						927				CH=CH ₂ (CH ₂ out-of Plane wag)
125								926		CH=CH ₂ (CH ₂ out-of Plane wag)
126									922	CH=CH ₂ (CH ₂ out-of Plane wag)
127							920			CH=CH ₂ (CH ₂ out-of Plane wag)
128				910						CH=CH ₂
129				867					867	O-C-C
130							866			C-H(bend)/ N-H wag amines
131					863					C-H(bend)/ N-H wag amines
132			860							C-H(bend)/ N-H wag amines
133								851		C-H(bend)/ N-H wag amines
134							850		850	C-H(bend)/ N-H wag amines
135				849						CH=CH ₂

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
136						833				bending vibrations of C-H
137	780									C-H out of plane vibration
138			764							C-C
139				731						C-O
140		723								(CH ₂) _n
141					708					C-H
142			707							C-H
143				683					683	O-C-C
144							682			O-C-C
145										C-Br/N-H wag amines
146	669		669			669				C-Br/N-H wag amines
147								668		C-Br/N-H wag amines

Table 4. 14. Cont'd.

Sl. No.	Cocoa powder	Oil	Maida	Sugar	Control cake	FDS powder	FDS cake	ODS powder	ODS cake	assignment
148				642						Ring glucofuran
149							579			C-I
150									578	C-I
151			576		576					C-I
152				552					552	O-C-O
153									537	C-I
154			529							C-I
155				471			471		471	O-C-C
156						467				Vibrations of PO ₄
157	466									Vibrations of PO ₄

4.4.7 Organoleptic evaluation of cakes during storage

The sensory evaluation of control cake, cake incorporated with FDS powder and that incorporated with ODS powder were estimated during storage and the results are given in Table 4.15, Table 4.16 and Table 4.17.

The organoleptic quality of the control cake decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.87 ± 0.35 , 8.93 ± 0.25 , 8.83 ± 0.38 , 8.87 ± 0.35 , 8.83 ± 0.38 , 8.77 ± 0.43 , 8.83 ± 0.38 and 8.87 ± 0.35 on the 0th day to 7.37 ± 0.49 , 6.90 ± 0.48 , 6.50 ± 0.51 , 5.73 ± 0.64 , 5.53 ± 0.51 , 6.17 ± 0.38 , 5.63 ± 0.49 and 5.67 ± 0.48 on the 28th day. The organoleptic quality of the cake incorporated with FDS powder decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.60 ± 0.50 , 8.67 ± 0.48 , 8.57 ± 0.50 , 8.63 ± 0.49 , 8.63 ± 0.49 , 8.53 ± 0.51 , 8.77 ± 0.43 and 8.60 ± 0.50 on the 0th day to 6.60 ± 0.50 , 6.37 ± 0.61 , 5.53 ± 0.68 , 4.83 ± 0.83 , 4.67 ± 0.61 , 4.90 ± 0.92 , 4.53 ± 0.57 and 4.60 ± 0.72 on the 28th day. The organoleptic quality of the cake incorporated with ODS powder decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.73 ± 0.45 , 8.83 ± 0.38 , 8.67 ± 0.48 , 8.67 ± 0.48 , 8.67 ± 0.48 , 8.60 ± 0.50 , 8.77 ± 0.43 and 8.63 ± 0.49 on the 0th day to 6.77 ± 0.57 , 6.50 ± 0.57 , 5.67 ± 0.61 , 5.03 ± 0.85 , 4.80 ± 0.61 , 5.10 ± 0.92 , 4.67 ± 0.66 and 4.73 ± 0.78 on the 28th day.

Table 4.15. Organoleptic evaluation of control cake during storage

Day	Attribute							
	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
Day 0	8.87 ± 0.35	8.93 ± 0.25	8.83 ± 0.38	8.87 ± 0.35	8.83 ± 0.38	8.77 ± 0.43	8.83 ± 0.38	8.87 ± 0.35
Day 7	8.40 ± 0.50	8.43 ± 0.50	8.37 ± 0.49	8.27 ± 0.64	8.03 ± 0.61	8.30 ± 0.53	8.40 ± 0.56	8.50 ± 0.51
Day 14	8.03 ± 0.56	7.97 ± 0.49	7.53 ± 0.51	7.43 ± 0.57	6.90 ± 0.48	7.07 ± 0.52	6.53 ± 0.51	6.83 ± 0.70
Day 21	7.77 ± 0.43	7.77 ± 0.43	6.97 ± 0.72	6.90 ± 0.76	6.73 ± 0.52	6.70 ± 0.47	6.33 ± 0.66	6.37 ± 0.76
Day 28	7.37 ± 0.49	6.90 ± 0.48	6.50 ± 0.51	5.73 ± 0.64	5.53 ± 0.51	6.17 ± 0.38	5.63 ± 0.49	5.67 ± 0.48

Table 4.16. Organoleptic evaluation of cake incorporated with FDS powder during storage

Day	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
Day 0	8.60 ± 0.50	8.67 ± 0.48	8.57 ± 0.50	8.63 ± 0.49	8.63 ± 0.49	8.53 ± 0.51	8.77 ± 0.43	8.60 ± 0.50
Day 7	8.10 ± 0.31	8.23 ± 0.43	7.90 ± 0.48	8.10 ± 0.48	8.10 ± 0.55	8.30 ± 0.53	8.47 ± 0.51	8.43 ± 0.50
Day 14	7.73 ± 0.52	7.63 ± 0.49	7.17 ± 0.65	7.00 ± 0.59	6.63 ± 0.49	6.63 ± 0.56	6.17 ± 0.70	6.17 ± 0.83
Day 21	7.50 ± 0.51	7.33 ± 0.48	6.53 ± 0.57	6.43 ± 0.57	5.63 ± 0.49	5.50 ± 0.57	5.43 ± 0.50	5.27 ± 0.45
Day 28	6.60 ± 0.50	6.37 ± 0.61	5.53 ± 0.68	4.83 ± 0.83	4.67 ± 0.61	4.90 ± 0.92	4.53 ± 0.57	4.60 ± 0.72

Table 4.17. Organoleptic evaluation of cake incorporated with ODS powder during storage

	Appearance	Colour	Odour	Taste	Mouth feel	Flavour	Texture	Overall acceptability
Day 0	8.73 ± 0.45	8.83 ± 0.38	8.67 ± 0.48	8.67 ± 0.48	8.67 ± 0.48	8.60 ± 0.50	8.77 ± 0.43	8.63 ± 0.49
Day 7	8.20 ± 0.41	8.27 ± 0.45	7.87 ± 0.35	8.20 ± 0.41	8.03 ± 0.61	8.30 ± 0.53	8.40 ± 0.56	8.40 ± 0.50
Day 14	7.83 ± 0.46	7.73 ± 0.45	7.17 ± 0.59	7.10 ± 0.61	6.73 ± 0.45	6.70 ± 0.53	6.33 ± 0.61	6.43 ± 0.73
Day 21	7.60 ± 0.50	7.43 ± 0.50	6.60 ± 0.62	6.63 ± 0.67	5.77 ± 0.43	5.80 ± 0.76	5.60 ± 0.62	5.50 ± 0.68
Day 28	6.77 ± 0.57	6.50 ± 0.57	5.67 ± 0.61	5.03 ± 0.85	4.80 ± 0.61	5.10 ± 0.92	4.67 ± 0.66	4.73 ± 0.78

4.4.8 Amino acid composition of cakes

The Amino acid composition of cakes were analysed and the results are given in Table 4.18.

Table 4.18. Amino acid composition of cakes

EAAs	Control cake (g/100 g)	ODS cake (g/100 g)	FDS cake (g/100 g)
Lysine	0.56	0.68	0.64
Therionine	0.31	0.49	0.46
Valine	0.22	0.46	0.42
Methionine	0.26	0.48	0.44
Isolucine	0.18	0.34	0.38
Phenylalanine	0.28	0.36	0.34
Histidine	0.12	0.34	0.38
Tyrosine	0.24	0.34	0.38
Cysteine	0.12	0.24	0.26
Leucine	0.74	1.12	1.14
Total EAAs	3.03	4.85	4.84
NEAA			
Aspartic acid	0.62	0.92	0.94
Glutamic acid	1.12	1.52	1.58
Arginine	0.81	0.96	1.02
Serine	0.78	0.96	0.96

EAA s	Control cake	ODS cake	FDS cake
Proline	0.48	0.52	0.56
Glycine	0.24	0.60	0.58
Alanine	0.32	0.62	0.64
Total NEAAs	4.37	6.1	6.00
Total AAs	7.40	10.95	10.84

Amino acid content in cakes increased with the incorporation of surimi in the product.

4.4.9 Minerals in cake

The mineral content in cakes incorporated with surimi powder were analysed and the results are given in Table 4.17.

Table 4.19. Minerals in cakes

Mineral	Control cake ($\times 10^{-2}$ g/kg)	Cake with ODS powder ($\times 10^{-2}$ g/kg)	Cake with FDS powder ($\times 10^{-2}$ g/kg)
Phosphorus	66 $\pm$ 5	74 $\pm$ 12	81 $\pm$ 15
Calcium	1.7 $\pm$ 0.5	2.1 $\pm$ 0.1	1.9 $\pm$ 1.3
Zinc	1.2 $\pm$ 0.6	1.5 $\pm$ 0.4	1.6 $\pm$ 0.1
Iron	3.1 $\pm$ 0.3	3.8 $\pm$ 0.2	4.1 $\pm$ 0.6

The phosphorus, calcium, zinc and iron content were $(66 \pm 5) \times 10^{-2}$ g/kg, $(1.7 \pm 0.5) \times 10^{-2}$ g/kg, $(1.2 \pm 0.6) \times 10^{-2}$ g/kg and $(3.1 \pm 0.3) \times 10^{-2}$ g/kg, respectively in control cake, $(74 \pm 12) \times 10^{-2}$ g/kg, $(2.1 \pm 0.1) \times 10^{-2}$ g/kg, $(1.5 \pm 0.4) \times 10^{-2}$ g/kg and $(3.8 \pm 0.2) \times 10^{-2}$ g/kg, respectively in ODS cake and $(81 \pm 15) \times 10^{-2}$ g/kg, $(1.9 \pm 1.3) \times 10^{-2}$ g/kg, $(1.6 \pm 0.1) \times 10^{-2}$ g/kg and $(4.1 \pm 0.6) \times 10^{-2}$ g/kg, respectively in FDS cake.

V. DISCUSSION

Powdered surimi, the dry form of concentrated myofibrillar protein, is a useful raw material for making various fish-based products owing to its good physicochemical properties (Santana et al., 2012). Surimi powder possesses many advantages compared to frozen surimi like easy handling, storage convenience and usefulness in dry mixtures (Green et al., 1985). In this study, surimi powder from itoyori surimi (from thread fin bream) was prepared and used to formulate bakery products.

5.1 Surimi powder

The structure of bakery products is a very important parameter for consumers' acceptance and hence proteins are essential in many bakery product formulations as foaming ingredients (Movahhed, 2016) and emulsifying property is another equally important property during baking. Meenachi (2016) reported that the emulsion capacity of surimi powder prepared by different methods (spray drying, freeze drying and cabinet drying) from black rohu ranged between 68.58% and 70.63% and the foaming capacity ranged between 30.78% and 52.44%. In the present study, the emulsion capacity, emulsion stability, foaming capacity and foaming stability of freeze dried surimi (FDS) powder were $70.67 \pm 1.15\%$, $54.67 \pm 1.15\%$, $48.67 \pm 1.15\%$ and $5.13 \pm 0.12\%$, respectively whereas that of oven dried surimi (ODS) powder were $68.67 \pm 1.15\%$, $51.33 \pm 0.58\%$, $45.33 \pm 0.58\%$ and $4.2 \pm 0.00\%$, respectively. Emulsion stability is important phenomena for thick consistency in biscuits baking and good foaming properties with flexible protein molecules reduce surface tension and are hence important properties in baked products

(Prajapati et al., 2015). Hence, higher the emulsion and foam properties, better the quality of surimi powder.

Majumder et al., 2017 studied the final proximate composition for surimi powder obtained from Tilapia (*Oreochromis mossambicus*) and reported $10.55 \pm 0.08\%$, $65.32 \pm 0.66\%$, $1.15 \pm 0.02\%$, $2.42 \pm 0.04\%$ and $20.56 \pm 0.26\%$ for moisture, protein, lipid, ash and carbohydrates, respectively. Similarly, in the present study, moisture, ash, protein, fat and carbohydrates contents of FDS powder were $3.25 \pm 0.30\%$, $1.79 \pm 0.10\%$, $68.96 \pm 0.18\%$, $2.00 \pm 0.07\%$ and $24.01 \pm 0.42\%$, respectively while that of ODS powder were, $5.54 \pm 0.26\%$, $1.89 \pm 0.17\%$, $67.12 \pm 0.42\%$, $1.99 \pm 0.12\%$ and $23.45 \pm 0.91\%$, respectively. In this study, slightly higher quantity of moisture was removed during the freeze drying as compared to oven drying of surimi, thereby resulting in lower moisture content and higher protein content in FDS powder as compared to ODS powder.

In the present study, TBARS value of FDS and ODS powder on the 0th month were $0.23 \mu\text{M/g}$ and $0.25 \mu\text{M/g}$, respectively and gradually increased to $0.76 \mu\text{M/g}$ and $0.76 \mu\text{M/g}$, respectively by the 12th month, while the peroxide values increased from $0.38 \text{ m.eq.O}_2/\text{Kg}$ and $0.45 \text{ m.eq.O}_2/\text{Kg}$, respectively on the 0th month to $1.01 \text{ m.eq.O}_2/\text{Kg}$ and $1.22 \text{ m.eq.O}_2/\text{Kg}$ by the 12th month, respectively and free fatty acid increased from 0.67% and 0.63% , respectively on the 0th month to 1.32% and 1.37% by the 12th month, respectively, which were all within the acceptable limits of $2 \text{ mg malonaldehyde/Kg}$ of TBARS (Zanardi et al., 2004). Similarly, Majumder et al. (2017) reported acceptable levels of TBARS, PV and FFA in tilapia surimi powder.

The total plate count of black rohu protein powder ranged between 1.40×10^3 and 1.45×10^3 cfu/g (Meenachi, 2016). In the present study, the total plate count of FDS and ODS powder were 1.79 ± 0.10 logcfu/g and 1.74 ± 0.13 logcfu/g on the 0th day and gradually increased to 3.08 ± 0.06 logcfu/g and 3.09 ± 0.06 logcfu/g, respectively by the 12th month, which were within the acceptable limit of 10^6 cfu/g (Ozogul et al., 2011; Meenachi, 2016). Fungal count was not detected in both types of surimi powder.

5.2 Biscuit

Chocolate biscuits were prepared by incorporating FDS powder and ODS powder along with control biscuit without surimi powder. Abraha et al. (2018a) reported that biscuits fortified with sturgeon fillet protein concentrate had improved nutritional and proximate composition with moisture content in the range 4.75% to 4.76%, protein content in the range 14.63% to 19.52%, fat content in the range 16.20% to 16.50% and ash content in the range 1.53% to 1.66%. Similarly, in the present study, the protein content increased significantly ($p < 0.05$) with increase in addition of surimi powder and hence, there was a decrease in carbohydrates content. The moisture, ash, fat, protein and carbohydrates contents in control biscuit, biscuit incorporated with 10% FDS, biscuit incorporated with 20% FDS and biscuit with 30% FDS were $2.19 \pm 0.09\%$, $1.26 \pm 0.05\%$, $25.26 \pm 0.23\%$, $6.22 \pm 0.09\%$ and $65.07 \pm 0.27\%$, respectively, $2.38 \pm 0.06\%$, $1.73 \pm 0.06\%$, $24.83 \pm 0.04\%$, $9.21 \pm 0.11\%$ and $61.85 \pm 0.15\%$, respectively, $2.61 \pm 0.21\%$, $1.79 \pm 0.10\%$, $24.27 \pm 0.08\%$, $12.14 \pm 0.17\%$ and $59.19 \pm 0.22\%$, respectively and $2.68 \pm 0.15\%$, $1.86 \pm 0.05\%$, $24.25 \pm 0.21\%$, $14.85 \pm 0.21\%$ and $56.36 \pm 0.02\%$,

respectively and in biscuit incorporated with 10% ODS, biscuit incorporated with 20% ODS and biscuit with 30% ODS were $2.01 \pm 0.08\%$, $1.52 \pm 0.06\%$, $24.90 \pm 0.03\%$, $9.00 \pm 0.09\%$ and $62.56 \pm 0.08\%$, respectively, $2.36 \pm 0.16\%$, $1.66 \pm 0.06\%$, $24.86 \pm 0.20\%$, $11.55 \pm 0.15\%$ and $59.57 \pm 0.27\%$, respectively and $2.58 \pm 0.10\%$, $1.73 \pm 0.05\%$, $24.47 \pm 0.18\%$, $13.97 \pm 0.23\%$ and $57.25 \pm 0.33\%$, respectively. Similarly, the Protein content in control biscuit was 9.51% and in biscuit fortified with 1%, 2% and 3% carp fish protein concentrate were 10.22%, 11.10% and 12% and in that with shark fish protein concentrate were 10.24%, 11.21% and 12.11%, respectively (Mohamed et al., 2014); however, the preparation of fish protein concentrate in this method involves the use of chemicals (NaHCO_3 and ethanol) whereas in the present study, no such chemicals were used. Nevertheless, Abraha et al. (2018b) observed that the nutritional and proximate composition of biscuits improved with replacing 7% and 10% of low gluten wheat flour with sturgeon fillet powder and reported moisture content in the range of 6.77% to 7.65, protein in the range of 13.23% to 17.12, fat in the range of 15.57% to 15.85 and ash in the range of 0.84% to 0.92%. However, Soni et al. (2018) reported that protein content increased more than two fold from 2.91 in control cookies to 6.83% in cookies with 20% of the refined wheat flour was replaced with chickpea flour and also reported that the moisture content was below 2%. However, there was no significant difference between protein contents of biscuits with 10% freeze dried surimi powder and biscuits with 10% oven dried surimi powder. Nutritionally, biscuits with 30% surimi powder were found to be better than the other biscuits. Ernst et al. (2014) reported that biscuits prepared incorporating animal meat was nutritionally better

than that having similar protein but prepared from plant source. However, as fish protein is considered superior to animal protein, the biscuits with surimi powder can be regarded as an excellent protein supplement. Moreover, the amino acid content of the product improved. Similar results were recorded by Abraha et al. (2018a) in biscuit incorporated with fish fillet protein concentrate in which the methionine and cysteine contents significantly increased from 0.07 and 0.05 g/100 g to 0.49 and 0.23, respectively. However, in the present study, the mineral content did not increase much in the products incorporated with surimi powder, probably due to the absence of bone particles in surimi powder.

In the present study, as the concentration of surimi powder increased greater than 10%, the sensory acceptability decreased. There was no significant difference ($p>0.05$) among the overall acceptability of control biscuits and biscuits with 10% freeze dried surimi powder and biscuits with 10% oven dried surimi powder. The biscuits with 10% surimi powder were found to have equal acceptability as control biscuits. Similarly, Mohamed et al. (2014) reported that the biscuits fortified with 1%, 2% and 3% carp fish protein concentrate that with shark fish protein concentrate had similar acceptance as the biscuits without fish protein concentrate. In the present study, biscuits with 20% surimi powder also had acceptable scores. There was no significant difference among the overall acceptability of biscuits with oven dried and with freeze dried surimi powder with same concentrations of surimi powder. Similarly, biscuits incorporated with 10% sturgeon fish fillet powder were the most liked and had the highest overall acceptability (8.60) among other biscuits (Abraha et al. 2018b). Nevertheless, biscuits added with 10% crickets to improve

nutritional quality had significantly lower acceptance than milk biscuits (Homann et al., 2017). In another study, Kumar et al. (2015) reported that oat bran incorporated chicken meat biscuit were found to have comparatively better sensory characteristics than wheat bran incorporated meat biscuits and control throughout the storage period of 180 days. However, in the present study, the organoleptic quality of the control biscuit decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.90 ± 0.31 , 8.97 ± 0.18 , 8.83 ± 0.38 , 8.90 ± 0.31 , 8.80 ± 0.48 , 8.73 ± 0.52 , 8.83 ± 0.38 and 8.90 ± 0.31 , respectively on the 0th day to 7.03 ± 0.49 , 7.13 ± 0.51 , 7.07 ± 0.45 , 6.77 ± 0.43 , 6.53 ± 0.51 , 6.80 ± 0.41 , 6.33 ± 0.48 and 6.70 ± 0.47 , respectively on the 120th day. The organoleptic quality of the biscuit incorporated with FDS powder decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.90 ± 0.31 , 8.97 ± 0.18 , 8.73 ± 0.45 , 8.83 ± 0.38 , 8.73 ± 0.52 , 8.70 ± 0.53 , 8.70 ± 0.47 and 8.83 ± 0.38 , respectively on the 0th day to 6.50 ± 0.51 , 6.47 ± 0.51 , 6.20 ± 0.48 , 5.67 ± 0.48 , 4.63 ± 0.61 , 4.93 ± 0.91 , 4.67 ± 0.48 and 4.53 ± 0.51 , respectively on the 120th day. The organoleptic quality of the biscuit incorporated with ODS powder decreased during storage. The scores for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.90 ± 0.31 , 8.97 ± 0.18 , 8.67 ± 0.48 , 8.83 ± 0.38 , 8.70 ± 0.53 , 8.70 ± 0.53 , 8.70 ± 0.47 and 8.83 ± 0.38 , respectively on the 0th day to 6.60 ± 0.50 , 6.53 ± 0.51 , 6.27 ± 0.45 , 5.70 ± 0.47 , 4.87 ± 0.68 , 5.07 ± 0.91 , 4.77 ± 0.43 and 4.67 ± 0.55 , respectively on the 120th day. The change in overall

acceptability of the products during any two consecutive sampling intervals were significant ($p < 0.05$). The surimi powder added biscuits were acceptable upto the 100th day. Jaiswal et al. (2015) assessed the sensory evaluation and texture profile analysis of chicken meat biscuits prepared by replacement of refined wheat flour with different levels (40%, 50% and 60%) of chicken meat powder and reported that the replacement of refined wheat flour with different levels of chicken meat powder had significant effect appearance and colour, texture values, flavour, meat intensity, saltiness and overall acceptability in comparison with control in aerobic packaging conditions and 50% chicken meat powder added biscuits obtained the highest scores for overall acceptability among all treatments. They also reported that the overall mean acceptability values of control and treatments decreased significantly over storage period in aerobic packaging.

Storage stability of biscuits incorporated with surimi powder were analyzed by estimating the TBARS value, peroxide value, free fatty acid value and microbial quality during their storage. Kumar et al. (2015) reported that the bran treated samples were found with improved oxidative stability as measured by free fatty acids and thiobarbituric acid reactive substances value during storage period of 180 days. In the present study, TBARS values of control biscuit, biscuit incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.08 $\mu\text{M/g}$, 0.24 $\mu\text{M/g}$ and 0.25 $\mu\text{M/g}$, respectively and gradually increased to 0.36 $\mu\text{M/g}$, 0.74 $\mu\text{M/g}$ and 0.76 $\mu\text{M/g}$, respectively by the 120th day, peroxide values on the 0th day were $0.41 \pm 0.01 \text{ m.eq.O}_2/\text{Kg}$, $0.78 \pm 0.00 \text{ m.eq.O}_2/\text{Kg}$ and $0.81 \pm 0.03 \text{ m.eq.O}_2/\text{Kg}$, respectively and gradually increased to $1.73 \pm 0.01 \text{ m.eq.O}_2/\text{Kg}$, 2.31 ± 0.01

m.eq.O₂/Kg and 2.34 ± 0.03 m.eq.O₂/Kg, respectively by the 120th day and free fatty acid on the 0th day were $0.50 \pm 0.02\%$, $0.66 \pm 0.02\%$ and $0.59 \pm 0.00\%$, respectively and gradually increased to $1.11 \pm 0.04\%$, $1.34 \pm 0.02\%$ and $1.33 \pm 0.02\%$, respectively by the 120th day. Mohamed et al. (2014) revealed that the Peroxide value and Thiobarbituric acid number increased gradually up to the end of the storage time in all biscuit samples prepared by fortification with carp fish protein concentrate and shark fish protein concentrate.

Abraha et al. (2018a) observed the microbial and physico- chemical results of biscuit supplemented with sturgeon fillet protein concentrate and reported that shelf life was more than 6 months. The total plate count of control biscuits, biscuits incorporated with FDS powder and that incorporated with ODS powder were not detected on the 0th day and were 1.98 ± 0.15 logcfu/g, 1.97 ± 0.07 logcfu/g and 1.92 ± 0.14 logcfu/g on the 15th day and then gradually increased to 2.97 ± 0.04 logcfu/g, 2.97 ± 0.05 logcfu/g and 2.99 ± 0.03 logcfu/g, respectively on the 120th day. However, fungal count was not detected in any of biscuits. However, TPC in types of biscuits during storage was lower than $10^4 - 10^6$ cfu/g, the maximum permissible level of total aerobic colony of ready-to-eat foods as given by Fylde Borough Council extracted from manual of PHLSG (2008).

In the present study, O-H bond, probably from hydroxyl ion or water molecule between 3326 cm^{-1} and 3560 cm^{-1} were prominent in biscuits. Common peaks around 2923 cm^{-1} and 2853 cm^{-1} probably from C-H/N-H were present in all the biscuits. Shifts in peak around 1638 cm^{-1} and 1550 cm^{-1} indicates changes in protein structure Liu et al. (2018). In the present study, the shifts of peak around 1638 cm^{-1}

and 1550 cm^{-1} was present in biscuits as compared to the ingredients suggesting a change in protein structure.

The production cost for preparing control biscuits was Rs. 160/kg, whereas that for biscuits with 10% oven dried surimi powder was Rs. 200/kg and for biscuits with 10% freeze dried surimi powder were Rs. 235/kg. However, the rate of commercially available biscuits was around the same as that of control biscuits. Preparation of biscuits in commercial scale can reduce the input cost.

5.3 Bread

Breads were prepared by incorporating different proportions of FDS and ODS powder and their nutritional characteristics were evaluated. Adeleke and Odedeji (2010) reported that the protein content of the control sample was 9.08% while the values for fortified bread samples ranged between 18.01 and 10.59% (80% wheat flour: 20% Tilapia Fish Protein Flour). Centenaro et al. (2007) observed that increase in concentration of cabrinha (*Prionotus punctatus*) mince, when incorporated in wet or dry form increased the protein content and decreased the carbohydrates content of bread. Similarly, an increase in protein content with increase in surimi powder was evident in this study. The moisture, ash, fat, protein and carbohydrates content in control bread were $20.49 \pm 0.07\%$, $0.30 \pm 0.00\%$, $3.46 \pm 0.02\%$, $8.06 \pm 0.08\%$ and $67.69 \pm 0.07\%$, respectively, while in bread incorporated with 5% FDS powder were $20.41 \pm 0.10\%$, $0.46 \pm 0.06\%$, $3.51 \pm 0.10\%$, 10.55 ± 0.31 and $65.07 \pm 0.38\%$, respectively, in bread incorporated with 10% FDS powder were $20.45 \pm 0.19\%$, $0.73 \pm 0.06\%$, $3.62 \pm 0.03\%$, $13.36 \pm 0.04\%$ and $61.84 \pm 0.23\%$, respectively, in bread incorporated with 15% FDS

powder were $20.65 \pm 0.05\%$, $0.93 \pm 0.06\%$, $3.63 \pm 0.06\%$, $15.14 \pm 0.21\%$ and $59.66 \pm 0.29\%$, respectively, in bread incorporated with 5% ODS powder were $20.43 \pm 0.20\%$, $0.43 \pm 0.12\%$, $3.57 \pm 0.06\%$, $10.38 \pm 0.23\%$ and $65.19 \pm 0.44\%$, respectively, in bread incorporated with 10% FDS powder were $20.73 \pm 0.16\%$, $0.63 \pm 0.06\%$, $63.54 \pm 0.02\%$, $13.21 \pm 0.11\%$ and $61.89 \pm 0.28\%$, respectively and in bread incorporated with 15% FDS powder were $20.38 \pm 0.27\%$, $0.80 \pm 0.10\%$, $3.61 \pm 0.05\%$, $14.45 \pm 0.20\%$ and $60.76 \pm 0.47\%$, respectively. Similarly, Monteiro et al. (2018) reported that bread formulations with different levels of tilapia-waste flour increased the lipid, protein and ash contents, and decreased the levels of carbohydrates and total dietary fibre at 5% enhanced the nutritional value. Bastos et al., 2014 studied bread products based on the addition of flour from Red-tailed Brycon (*Brycon cephalus*) processing residue and then evaluate the chemical and sensory qualities of the products and observed that in relation to a standard bread formulation without fish flour and reported that the addition of fish flour to bread formulations resulted in products with not only higher contents of protein, essential fatty acids, and minerals, especially calcium and phosphorus, but also lower contents of carbohydrates. Nevertheless, in the present study, there was no significant improvement in mineral profile as surimi powder was devoid of bones. However, the improvement in amino acid composition was prominent, especially methionine (0.79g/100 g in ODS bread and 0.83g/100 g in FDS bread) and cysteine (0.15g/100 g) in both kinds of surimi added bread.

The sensory evaluation of bread incorporated with FDS powder and that incorporated with ODS powder were estimated. Bastos et al. (2014) reported that

the bread with red-tailed brycon processing residue flour received sensory acceptance better than or as good as that of a bread formulation without fish flour. Monteiro et al. (2018) reported that incorporating tilapia-waste flour obtained acceptable sensory scores for bread, constituting a potential strategy to satisfy consumer and industry requirements. In the present study, the sensory scores of bread on an average for control bread, bread incorporated with 5%, 10% and 15% FDS powder were 8.77 ± 0.43 , 8.43 ± 0.50 , 8.33 ± 0.48 and 7.27 ± 0.45 , respectively for the attribute appearance, 8.90 ± 0.31 , 8.47 ± 0.51 , 8.37 ± 0.49 and 6.70 ± 0.47 , respectively for the attribute colour, 8.80 ± 0.41 , 8.60 ± 0.50 , 8.43 ± 0.50 and 5.30 ± 0.47 , respectively for the attribute odour, 8.83 ± 0.38 , 8.70 ± 0.47 , 8.57 ± 0.50 and 4.67 ± 0.48 , respectively for the attribute taste, 8.80 ± 0.41 , 8.67 ± 0.48 , 8.57 ± 0.50 and 6.23 ± 0.43 , respectively for the attribute mouth feel, 8.73 ± 0.45 , 8.57 ± 0.50 , 8.43 ± 0.50 and 4.60 ± 0.50 , respectively for the attribute flavour, 8.80 ± 0.41 , 8.73 ± 0.45 , 8.63 ± 0.49 and 6.27 ± 0.45 , respectively for the attribute texture and, 8.77 ± 0.43 , 8.50 ± 0.51 , 8.47 ± 0.51 and 4.60 ± 0.50 , respectively for overall acceptability. The sensory scores of bread incorporated with ODS powder on an average for control bread, bread incorporated with 5%, 10% and 15% ODS powder were 8.77 ± 0.43 , 8.27 ± 0.45 , 8.13 ± 0.35 and 6.93 ± 0.52 , respectively for the attribute appearance, 8.90 ± 0.31 , 8.23 ± 0.43 , 8.03 ± 0.49 and 6.40 ± 0.50 , respectively for the attribute colour, 8.80 ± 0.41 , 8.53 ± 0.51 , 8.57 ± 0.50 and 5.20 ± 0.41 , respectively for the attribute odour, 8.83 ± 0.38 , 8.67 ± 0.48 , 8.53 ± 0.51 and 4.53 ± 0.51 , respectively for the attribute taste, 8.80 ± 0.41 , 8.57 ± 0.50 , 8.43 ± 0.50 and 6.03 ± 0.41 , respectively for the attribute mouth

feel, 8.73 ± 0.45 , 8.33 ± 0.48 , 7.73 ± 0.64 and 4.50 ± 0.51 , respectively for the attribute flavour, 8.80 ± 0.41 , 8.67 ± 0.48 , 8.50 ± 0.51 and 6.17 ± 0.38 , respectively for the attribute texture and, 8.77 ± 0.43 , 8.27 ± 0.45 , 8.03 ± 0.61 and 4.40 ± 0.62 , respectively for overall acceptability. However, the score for the attribute colour was slightly lower for ODS powder incorporated bread as compared to FDS powder incorporated bread. Bread with 15% surimi powder were not acceptable. Nevertheless, Centenaro et al. (2007) observed that increase in concentration of cabrinha (*Prionotus punctatus*) mince, when incorporated in wet or dry form reduced the acceptability of bread. The sensory evaluation of control bread, bread incorporated with FDS powder and that incorporated with ODS powder were estimated during storage and the results revealed that the organoleptic quality of the control bread significantly ($p < 0.05$) decreased during storage. The scores of control bread for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.77 ± 0.43 , 8.90 ± 0.31 , 8.80 ± 0.41 , 8.83 ± 0.38 , 8.80 ± 0.41 , 8.73 ± 0.45 , 8.80 ± 0.41 and 8.77 ± 0.43 , respectively on the 0th day to 6.83 ± 0.59 , 6.57 ± 0.50 , 6.07 ± 0.64 , 5.27 ± 0.87 , 5.10 ± 0.61 , 5.47 ± 0.82 , 5.13 ± 0.73 and 5.13 ± 0.82 , respectively on the 8th day. The scores of FDS bread for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.33 ± 0.48 , 8.37 ± 0.49 , 8.43 ± 0.50 , 8.57 ± 0.50 , 8.57 ± 0.50 , 8.43 ± 0.50 , 8.63 ± 0.49 and 8.47 ± 0.51 , respectively on the 0th day to 6.47 ± 0.63 , 6.20 ± 0.66 , 5.43 ± 0.77 , 4.70 ± 0.79 , 4.53 ± 0.51 , 4.70 ± 0.88 , 4.47 ± 0.51 and 4.47 ± 0.63 , respectively on the 8th day. The scores of ODS bread for appearance, colour, odour, taste, mouth feel, flavour,

texture and overall acceptability decreased from 8.13 ± 0.35 , 8.03 ± 0.49 , 8.57 ± 0.50 , 8.53 ± 0.51 , 8.43 ± 0.50 , 7.73 ± 0.64 , 8.50 ± 0.51 and 8.03 ± 0.61 , respectively on the 0th day to 6.57 ± 0.50 , 6.30 ± 0.70 , 5.47 ± 0.57 , 4.90 ± 0.84 , 4.60 ± 0.56 , 4.77 ± 0.90 , 4.53 ± 0.57 and 4.47 ± 0.63 , respectively on the 8th day. Nikkila et al. (1976) reported that the supplemented breads were well accepted when 10% of bread flour was replaced by fish protein concentrate and such a supplementation with the best test fish protein concentrate used elevated the protein efficiency ratio of the bread to equal that of casein. Adeleke and Odedeji (2010) reported (80% wheat flour: 20% Tilapia Fish Protein Flour (TFPF) having the highest value and the result of organoleptic analysis revealed that there was no significant difference among the samples in term of taste, aroma, crust and crumb colour and overall acceptability.

There was a significant difference ($p < 0.05$) between TBARS, PV and FFA of control bread and bread incorporated with both kinds of surimi powder. However, there was no significant difference ($p > 0.05$) between the indices of rancidity of FDS powder incorporated bread and ODS powder incorporated bread. Moreover, there was no significant difference ($p > 0.05$) between the indices of rancidity of all types of bread on consecutive sampling interval during storage except for FDS powder incorporated bread in which there was a significant increase ($p < 0.05$) in TBARS and PV between 2nd and 4th day of storage and PV of ODS powder incorporated bread between 4th and 6th day. The TBARS values of control bread, bread incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.66 \mu\text{M/g}$, $0.72 \mu\text{M/g}$ and $0.72 \mu\text{M/g}$,

respectively and gradually increased to 0.68 $\mu\text{M/g}$, 0.74 $\mu\text{M/g}$ and 0.74 $\mu\text{M/g}$, respectively by the 8th day. The peroxide value of control bread was 0.28 m.eq.O₂/Kg and did not increase during storage period. The peroxide values of bread incorporated with FDS powder and that incorporated with ODS powder on the 0th day were 0.40 m.eq.O₂/Kg and 0.42 m.eq.O₂/Kg, respectively and gradually increased to 0.42 m.eq.O₂/Kg and 0.44 m.eq.O₂/Kg, respectively by the 8th day. The free fatty acid in control bread, bread incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.53 \pm 0.02\%$, $0.71 \pm 0.02\%$ and $0.72 \pm 0.02\%$, respectively. The values of all indices of rancidity for all bread were within the acceptable limits.

In the present study, transmittance around the region 900–1150 cm^{-1} decreased in surimi powder incorporated bread of both types indicating starch crystallization and starch retrogradation. Similarly, unit absorbance increased in bread in the band 900–1150 cm^{-1} , which corresponds to the “saccharides” group indicating progressive starch crystallization and starch retrogradation and the bands in the region 3000–3600 cm^{-1} corresponded to O-H bond stretching vibration¹¹. In the present study, transmittance was higher in control bread in the O-H region as compared to the two types of surimi powder incorporated bread indicating the higher water holding capacity in the surimi incorporated bread, probably owing to the higher myofibrillar content sourced from surimi. Peaks within 1500–1800 cm^{-1} region are associated with Amide I and II signals of protein, carbonyl stretching modes of pectic polysaccharides and the O—H bending mode of water⁹. The shifts in peaks around this region reveal the possibility of change in

protein structure during baking of bread. Moreover, the decrease in transmittance around the peak 1638 indicates the higher concentration of protein in two types of surimi powder incorporated bread as compared to the control bread. The surimi powder incorporated bread of both types does not have any negative effects on the functional characteristics of bread and also the protein content has increased.

The production cost for preparing control bread was Rs. 25/200g, whereas that for bread with 10% oven dried surimi powder was Rs. 29/200g and for bread with 10% freeze dried surimi powder was Rs. 32/200g. However, the rate of commercially available bread was around the same as that of control bread. Preparation in commercial scale can reduce the input cost.

5.4 Cake

Chocolate cakes were prepared by incorporating different proportions of FDS and ODS powder and their nutritional characteristics were evaluated. Pi et al. (2017) observed that the dolphinfish chiffon cake (30%) showed highest moisture content (49.32%) and moisture content of file fish added cake and control were 46.84% and 43.22% respectively. They also observed that the dolphinfish chiffon cake (30%) showed highest fat content (12.63%) and fat content of file fish added cake and control were 12.44% and 12.42% respectively. They reported that the file fish chiffon cake (30%) showed highest protein content (12.87%) and protein content of dolphin fish added cake and control were 11.42% and 8.68% respectively. They also reported that the control chiffon cake (30%) showed highest ash content (1.35%) and ash content of dolphin fish (30%) added cake and file fish added cake were 1.03% and 0.88% respectively. In the present study,

the moisture, ash, fat, protein and carbohydrates contents in control cake, cake incorporated with 10%, 20% and 30% FDS powder, cake incorporated with 10%, 20% and 30% ODS powder were $22.46 \pm 0.56\%$, $0.37 \pm 0.06\%$, $28.49 \pm 0.10\%$, $6.11 \pm 0.05\%$ and 42.58 ± 0.64 , respectively, $22.13 \pm 0.15\%$, $0.80 \pm 0.10\%$, $28.82 \pm 0.16\%$, $8.13 \pm 0.06\%$ and $40.12 \pm 0.32\%$, respectively, $24.84 \pm 0.84\%$, $1.06 \pm 0.06\%$, $29.14 \pm 0.12\%$, $10.08 \pm 0.20\%$ and $34.87 \pm 0.73\%$, respectively, and $27.03 \pm 1.51\%$, $1.20 \pm 0.00\%$, $29.83 \pm 0.26\%$, $12.09 \pm 0.22\%$ and $29.85 \pm 1.37\%$, respectively, were $22.53 \pm 0.11\%$, $0.80 \pm 0.10\%$, $28.21 \pm 0.06\%$, $8.03 \pm 0.03\%$ and $40.44 \pm 0.19\%$, respectively, $24.96 \pm 0.37\%$, $1.06 \pm 0.15\%$, $28.92 \pm 0.12\%$, $10.08 \pm 0.18\%$, and $34.97 \pm 0.55\%$, respectively, and $26.79 \pm 0.33\%$, $1.23 \pm 0.06\%$, $29.73 \pm 0.57\%$, $11.92 \pm 0.22\%$ and $30.32 \pm 0.04\%$, respectively. However, the change in mineral profile was meager. In the present study, the amino acid composition in the surimi added cakes were higher than that of cake without surimi powder.

The sensory evaluation of cakes incorporated with FDS powder and that incorporated with ODS powder were evaluated. Pi et al. (2017) revealed that no significant differences were found between the original and fish chiffon cakes for the attributes of odour, texture, flavour, and overall acceptability; however, appearance of fish chiffon cake had lower score than the original chiffon cake. In the present study, sensory scores of cakes incorporated with FDS powder on an average for control cake, cake incorporated with 10%, 20% and 30% FDS powder were 8.87 ± 0.35 , 8.60 ± 0.50 , 8.60 ± 0.50 and 8.23 ± 0.63 , respectively for the attribute appearance, 8.93 ± 0.25 , 8.67 ± 0.48 , 8.57 ± 0.50 and 8.47 ± 0.57 ,

respectively for the attribute colour, 8.83 ± 0.38 , 8.57 ± 0.50 , 7.43 ± 0.50 and 4.83 ± 0.83 respectively for the attribute odour, respectively, 8.87 ± 0.35 , 8.63 ± 0.49 , 7.43 ± 0.50 and 3.73 ± 0.45 for the attribute taste, 8.83 ± 0.38 , 8.63 ± 0.49 , 7.40 ± 0.50 and 3.63 ± 0.49 , respectively for the attribute mouth feel, 8.77 ± 0.43 , 8.53 ± 0.51 , 6.83 ± 0.46 and 3.60 ± 0.50 , respectively for the attribute flavour, 8.83 ± 0.38 , 8.77 ± 0.43 , 7.03 ± 0.49 and 4.83 ± 0.53 , respectively for the attribute texture and 8.87 ± 0.35 , 8.60 ± 0.50 , 6.83 ± 0.46 and 3.77 ± 0.43 , respectively for overall acceptability. The sensory scores of cakes incorporated with ODS powder on an average for control cake, cake incorporated with 10%, 20% and 30% ODS powder were 8.87 ± 0.35 , 8.73 ± 0.45 , 8.47 ± 0.51 and 8.13 ± 0.63 , respectively for the attribute appearance, 8.93 ± 0.25 , 8.83 ± 0.38 , 8.50 ± 0.51 and 8.33 ± 0.66 , respectively for the attribute colour, 8.83 ± 0.38 , 8.67 ± 0.48 , 7.37 ± 0.49 and 4.73 ± 0.87 , respectively for the attribute odour, 8.87 ± 0.35 , 8.67 ± 0.48 , 7.33 ± 0.48 and 3.63 ± 0.49 , respectively, for the attribute taste, 8.83 ± 0.38 , 8.67 ± 0.48 , 7.33 ± 0.48 and 3.53 ± 0.51 , respectively for the attribute mouth feel, 8.77 ± 0.43 , 8.60 ± 0.50 , 6.77 ± 0.50 and 3.50 ± 0.51 , respectively for the attribute flavour, 8.83 ± 0.38 , 8.77 ± 0.43 , 6.90 ± 0.48 and 4.73 ± 0.58 , respectively for the attribute texture and, 8.87 ± 0.35 , 8.63 ± 0.49 , 6.73 ± 0.45 and 3.63 ± 0.49 respectively for overall acceptability. However, the acceptability of the cakes decreased during storage period. The scores of control cake for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.87 ± 0.35 , 8.93 ± 0.25 , 8.83 ± 0.38 , 8.87 ± 0.35 , 8.83 ± 0.38 , 8.77 ± 0.43 , 8.83 ± 0.38 and 8.87 ± 0.35 on the 0th day to $7.37 \pm$

0.49, 6.90 ± 0.48 , 6.50 ± 0.51 , 5.73 ± 0.64 , 5.53 ± 0.51 , 6.17 ± 0.38 , 5.63 ± 0.49 and 5.67 ± 0.48 on the 28th day. The scores of FDS cake for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.60 ± 0.50 , 8.67 ± 0.48 , 8.57 ± 0.50 , 8.63 ± 0.49 , 8.63 ± 0.49 , 8.53 ± 0.51 , 8.77 ± 0.43 and 8.60 ± 0.50 on the 0th day to 6.60 ± 0.50 , 6.37 ± 0.61 , 5.53 ± 0.68 , 4.83 ± 0.83 , 4.67 ± 0.61 , 4.90 ± 0.92 , 4.53 ± 0.57 and 4.60 ± 0.72 on the 28th day. The scores of ODS cake for appearance, colour, odour, taste, mouth feel, flavour, texture and overall acceptability decreased from 8.73 ± 0.45 , 8.83 ± 0.38 , 8.67 ± 0.48 , 8.67 ± 0.48 , 8.67 ± 0.48 , 8.60 ± 0.50 , 8.77 ± 0.43 and 8.63 ± 0.49 on the 0th day to 6.77 ± 0.57 , 6.50 ± 0.57 , 5.67 ± 0.61 , 5.03 ± 0.85 , 4.80 ± 0.61 , 5.10 ± 0.92 , 4.67 ± 0.66 and 4.73 ± 0.78 on the 28th day. Nevertheless, Pi et al. (2017) observed that the hardness of the dolphin fish (30%) added cake and file fish added cake were lower than that of the control after 1 and 2 days storage at 25°C and the hedonic scores of most attributes ranging from 6 to 7 indicated that panelists liked the original chiffon cake and fish chiffon cakes slightly.

Storage stability of cakes incorporated with surimi powder were analyzed by estimating TBARS value, peroxide value, free fatty acid value and microbial quality during their storage period. The increase in TBARS value of all types of cakes were significant ($p < 0.05$) between consecutive sampling intervals throughout the storage period. The TBARS values of control cake, cake incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.18 \mu\text{M/g}$, $0.32 \mu\text{M/g}$ and $0.35 \mu\text{M/g}$, respectively and gradually

increased to 0.22 $\mu\text{M/g}$, 0.39 $\mu\text{M/g}$ and 0.43 $\mu\text{M/g}$, respectively by the 30th day. The peroxide values of control cake, cake incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.71 \pm 0.01 \text{ m.eq.O}_2/\text{Kg}$, $0.91 \pm 0.01 \text{ m.eq.O}_2/\text{Kg}$ and $0.97 \pm 0.01 \text{ m.eq.O}_2/\text{Kg}$, respectively and gradually increased to $0.84 \pm 0.00 \text{ m.eq.O}_2/\text{Kg}$, $1.04 \pm 0.00 \text{ m.eq.O}_2/\text{Kg}$ and $1.07 \pm 0.01 \text{ m.eq.O}_2/\text{Kg}$, respectively by the 30th day. The free fatty acids in control cake, cake incorporated with FDS powder and that incorporated with ODS powder on the 0th day were $0.82 \pm 0.00\%$, $1.26 \pm 0.01\%$ and $1.30 \pm 0.01\%$, respectively and gradually increased to $0.96 \pm 0.00\%$, $1.37 \pm 0.01\%$ and $1.42 \pm 0.02\%$, respectively by the 30th day. The values of all indices of rancidity for all cakes were within the acceptable limits.

According to Pi et al. (2017), the microbiological load of all chiffon cake samples after 0 and 12 h baking were not detectable, reflecting a clean surface of the chiffon cake at the time of sampling and Aerobic Plate Counts (APCs) of all chiffon cake samples were higher than the upper microbial limit ($> 6 \log \text{ cfu/g}$) for seafood products after 2 days storage at 25°C . Similarly, in the present study, the total plate count of control cake, cake incorporated with FDS powder and that incorporated with ODS powder were not detected on the 0th day and were $1.59 \pm 0.26 \log \text{ cfu/g}$, $1.48 \pm 0.44 \log \text{ cfu/g}$ and $1.66 \pm 0.22 \log \text{ cfu/g}$ on the 7th day and then increased to $2.28 \pm 0.07 \log \text{ cfu/g}$, $2.25 \pm 0.11 \log \text{ cfu/g}$ and $2.28 \pm 0.05 \log \text{ cfu/g}$, respectively on the 28th day. Fungal count was not detected in any of cakes during the entire storage period.

In the present study, the FTIR spectra showed O-H bond, probably from

hydroxyl ion or water molecule between 3326 cm^{-1} and 3560 cm^{-1} were prominent in all the cakes. C-H expansion vibration peak probably due to the presence of unsaturated oil/linoleic acid were present in all the cake samples. Common peaks around 2923 cm^{-1} and 2853 cm^{-1} probably from C-H/N-H were present in all the cakes. N=H is probably the assignment of peaks around 2360 cm^{-1} in the products. Peaks around 3434 cm^{-1} , 2855 cm^{-1} , 1743 cm^{-1} , 1083 cm^{-1} , 1047 cm^{-1} , 1021 cm^{-1} , and 1156 cm^{-1} were obtained in the FTIR spectra of eggless cakes (Lin et al., 2017). Changes in protein structure of the cakes were indicated by shifts in peak around 1550 cm^{-1} .

The production cost for preparing control cakes was Rs. 10/piece, whereas that for cakes with 10% oven dried surimi powder was Rs. 12/ piece and for cakes with 10% freeze dried surimi powder was Rs. 14/ piece, where the average weight of each piece of cake is $47.5\pm 2.5\text{g}$. However, the rate of commercially available cakes was around the same as that of control cakes. Preparation of cakes in commercial scale can reduce the input cost.

5.5 Microstructure of bakery products

Microstructure analyses of control biscuits, FDS powder incorporated biscuits and ODS powder incorporated biscuits were observed. Scanning electron microscopy showed that biscuit produced with palm mid fraction had a heterogeneous air cells and open internal microstructure (Mamat and Hill, 2012). However, in the present study, a layer of lipid molecules was visible in all the products. Greater uniformity and compaction of the product was observed in control biscuit. Similar uniformity and compaction were observed by Tavares et al. (2016) in

gluten free sweet biscuits elaborated with rice bran, broken rice and okara. Moreover, in the present study, there was no difference observed between control and surimi added products. However, large airspaces were seen in control bread, probably due to the action of yeast. Similarly, structure of the bread was reported to be very fragile with open and larger pores (Datta et al., 2006). The sizes of the air spaces in FDS powder and ODS powder added bread were slightly reduced as compared to the control bread. Nevertheless, highly porous structure was a common characteristic feature of all types of bread. The darker colour of surimi powder was visible as spots in ODS powder incorporated bread, which might have lead to the slightly lower acceptability. Large numbers of pores were present in all the cakes. FDS powder incorporated cakes had higher number of micro-pores than control and ODS powder incorporated cakes. Evenness in structure was higher in control cake than FDS and ODS powder incorporated cakes.

VI. SUMMARY AND CONCLUSION

- Itoyori surimi (surimi from *Nemipterus* spp.) was purchased from Gadre Marine Pvt. Ltd, Brahmavar and was freeze dried using two different methods viz. freeze drying and oven drying, for which the conditions were optimized and both types of dried surimi were powdered to obtain freeze dried surimi (FDS) powder and oven dried surimi (ODS) powder. The optimum temperature for oven drying of surimi was $55 \pm 5^{\circ}\text{C}$. The optimal condenser temperature, freezing temperature and pressure for freeze drying the surimi were -50°C , -23°C and 0.5mbar, respectively for 8h.
- The proximate composition and functional properties viz. emulsion capacity, emulsion stability, foaming capacity and foaming stability of the surimi powders were examined along with shelf stability characteristics viz. TBARS value, peroxide value, free fatty acid and microbial quality characteristics viz. total plate count and total fungal count. Both types of surimi powder had stability parameters within the acceptable limits up to one year.
- Bakery products viz. biscuit, cake and bread were formulated using both types of surimi powder for which the proportions of surimi powder were optimized.
- Biscuits were prepared by incorporating different proportions (10%, 20% and 30%) of FDS and ODS powder and their different characteristics were evaluated. The proximate composition of biscuit incorporated with

FDS powder and biscuit incorporated with ODS powder were estimated. As the percentage of surimi powder increased, the protein content in biscuits significantly increased and the highest protein content was observed in 30% FDS powder incorporated biscuit followed by 30% ODS powder incorporated biscuit and the lowest in control biscuit. The carbohydrates content decreased with increase in concentration of both types of surimi powder and the highest was found in control biscuit and the lowest in 30% FDS powder incorporated biscuit.

- The sensory evaluation of biscuit incorporated with FDS powder and biscuit incorporated with ODS powder were estimated. The sensory scores of biscuit incorporated with FDS powder on an average for control biscuit, biscuits incorporated with 10%, 20% and 30% FDS powder were 8.90 ± 0.31 , 8.83 ± 0.38 , 6.43 ± 1.01 and 4.83 ± 0.99 , respectively for overall acceptability. The sensory scores of biscuit incorporated with ODS powder on an average for control biscuit, biscuits incorporated with 10%, 20% and 30% ODS powder were 8.90 ± 0.31 , 8.83 ± 0.38 , 6.40 ± 1.07 and 4.80 ± 1.00 , respectively for overall acceptability. The biscuit incorporated with 10% FDS powder and biscuit incorporated with 10% ODS powder were selected for further studies due to their higher acceptability as compared to biscuits incorporated with increased concentrations of both types of surimi powder.
- The amino acid composition of the control biscuit, biscuit incorporated with 10% FDS powder and biscuit incorporated with 10% ODS powder

were analysed and the increase in essential and non essential amino acids in both types of surimi powder added biscuits were observed.

- The mineral content of the control biscuit, biscuit incorporated with 10% FDS powder and biscuit incorporated with 10% ODS powder were analysed and it was observed that there was slight increase in mineral content viz. calcium, phosphorus, iron and zinc in both types of surimi powder added biscuits.
- Scanning electron microscopic images of control biscuit, biscuit incorporated with 10% FDS powder and biscuit incorporated with 10% ODS powder were observed. Results showed that a layer of lipid molecules was visible in all the products. Greater uniformity and compaction of the product was observed in control biscuit. There was no difference observed between control and surimi added products.
- FTIR spectra of the ingredients and biscuits were analyzed and the functional interaction that took place during the formulation and processing of biscuits were examined. Changes in protein structure during baking were evident from the spectral studies.
- Storage stability of biscuits incorporated with both types of surimi powder were analyzed by estimating their TBARS value, peroxide value, free fatty acid value and microbial quality during their storage. The values of all the parameters were within the acceptable levels during the storage period of 120 days.

- The sensory evaluation of control biscuit, biscuit incorporated with FDS powder and biscuit incorporated with ODS powder were estimated during storage. The organoleptic quality of the control biscuit decreased during storage. The scores for overall acceptability decreased from 8.90 ± 0.31 on the 0th day to 6.70 ± 0.47 on the 120th day. The organoleptic quality of the biscuit incorporated with FDS powder decreased during storage. The scores for overall acceptability decreased from 8.83 ± 0.38 on the 0th day to 4.53 ± 0.51 on the 120th day. The organoleptic quality of the biscuit incorporated with ODS powder decreased during storage. The scores for overall acceptability decreased from 8.83 ± 0.38 on the 0th day to 4.67 ± 0.55 on the 120th day and the shelf lives of the FDS powder incorporated biscuit and ODS powder incorporated biscuit were 100 days based on sensory evaluation.
- Breads were prepared by incorporating different proportions of FDS and ODS powder and their various characteristics were evaluated. The proximate composition of bread incorporated with 5%, 10% and 15% FDS powder and bread incorporated with 5%, 10% and 15% ODS powder were estimated. As the percentage of surimi powder increased, the protein content in bread significantly increased and the highest protein content was observed in 15% FDS powder incorporated bread followed by 15% ODS powder incorporated bread and the lowest in control bread. The carbohydrates content decreased with increase in concentration of both types of surimi powder and the highest was found in control bread

and the lowest in 15% FDS powder incorporated bread.

- The sensory evaluation of bread incorporated with FDS powder and bread incorporated with ODS powder were estimated. The sensory scores of bread incorporated with FDS powder on an average for control bread, bread incorporated with 5%, 10% and 15% FDS powder were 8.77 ± 0.43 , 8.50 ± 0.51 , 8.47 ± 0.51 and 4.60 ± 0.50 , respectively for overall acceptability, whereas sensory scores of bread incorporated with ODS powder on an average for bread incorporated with 5%, 10% and 15% ODS powder were 8.27 ± 0.45 , 8.03 ± 0.61 and 4.40 ± 0.62 , respectively for overall acceptability. Based on sensory evaluation, bread incorporated with 10% FDS powder and bread incorporated with 10% ODS powder were selected for further studies.
- The amino acid composition of the control bread, bread incorporated with 10% FDS powder and bread incorporated with 10% ODS powder were analysed and the increase in essential and non essential amino acids in both types of surimi powder added bread were observed.
- The mineral content of the control bread, bread incorporated with 10% FDS powder and bread incorporated with 10% ODS powder were analysed and it was observed that there was slight increase in minerals viz. calcium, phosphorus, iron and zinc in both types of surimi powder added bread.
- Scanning electron microscopic images of control bread, bread

incorporated with 10% FDS powder and bread incorporated with 10% ODS powder were observed. The results revealed that the large air spaces were seen in control bread, the sizes of the air spaces in FDS powder incorporated and ODS powder incorporated bread were slightly reduced as compared to the control bread, highly porous structure was a common characteristic feature of all types of bread and darker surimi powder was visible in ODS powder incorporated bread.

- FTIR spectra of ingredients and bread were analyzed to assess the functional interaction that took place during the formulation and processing of bread. Changes in protein structure during processing were evident from the present study.
- Storage stability of bread incorporated with surimi powder analyzed by estimating the TBARS value, peroxide value, free fatty acid value and microbial quality during their storage period. The TBARS values of control bread, bread incorporated with 10% FDS powder and bread incorporated with 10% ODS powder gradually increased during storage period. The peroxide value of control bread did not increase during storage period. The peroxide values of bread incorporated with FDS powder and bread incorporated with ODS powder gradually increased by the 8th day. The free fatty acid in control bread, bread incorporated with FDS powder and that incorporated with ODS powder did not vary significantly during a storage period of 8 days. All the stability parameters were within the acceptable levels.

- The sensory evaluation of control bread, bread incorporated with FDS powder and that incorporated with ODS powder were estimated during storage and the results revealed that the organoleptic quality of the control bread decreased during storage. The scores for overall acceptability of the control bread decreased from 8.77 ± 0.43 on the 0th day to 5.13 ± 0.82 on the 8th day. The organoleptic quality of the FDS bread decreased during storage. The scores for overall acceptability decreased from 8.47 ± 0.51 on the 0th day to 4.47 ± 0.63 on the 8th day. The organoleptic quality of the ODS bread decreased during storage. The scores for 8.03 $\pm$ 0.61 on the 0th day to 4.47 $\pm$ 0.63 on the 8th day. Bread incorporated with both types of surimi were acceptable up to 6 days.
- Cakes were prepared by incorporating different proportions (10%, 20% and 30%) of FDS and ODS powder and their various characteristics were evaluated. As the percentage of surimi powder increased, the protein content in cakes significantly increased and the highest protein content was observed in 30% FDS powder incorporated cake followed by 30% ODS powder incorporated cake and the lowest in control cake. The carbohydrates content decreased with increase in concentration of both types of surimi powder and the highest was found in control cake and the lowest in 30% FDS powder incorporated cake.
- The sensory evaluation of control cake, cake incorporated with FDS powder and cake incorporated with ODS powder were evaluated. The sensory scores of cake incorporated with FDS powder on an average for

control cake, cakes incorporated with 10%, 20% and 30% FDS powder were 8.87 ± 0.35 , 8.60 ± 0.50 , 6.83 ± 0.46 and 3.77 ± 0.43 , respectively for overall acceptability. The sensory scores of cakes incorporated with ODS powder on an average for cakes incorporated with 10%, 20% and 30% ODS powder were 8.63 ± 0.49 , 6.73 ± 0.45 and 3.63 ± 0.49 , respectively for overall acceptability. On the basis of sensory evaluation, cake incorporated with 10% FDS powder and cake incorporated with 10% ODS powder were selected for further studies.

- The amino acid composition of the control cake, cake incorporated with 10% FDS powder and cake incorporated with 10% ODS powder were analysed and the increase in essential and non essential amino acids in both types of surimi powder added cakes were observed.
- The mineral content of the control cake, cake incorporated with 10% FDS powder and cake incorporated with 10% ODS powder were analysed and it was observed that there was slight increase in mineral contents viz. calcium, phosphorus, iron and zinc in both types of surimi powder incorporated cakes.
- Scanning electron microscopic images of control cake, cake incorporated with 10% FDS powder and cake incorporated with 10% ODS powder were observed. The results revealed that the large number of pores were present in all the cakes. FDS powder incorporated cake had higher number of micro-pores than control and ODS powder incorporated cake.

Evenness in structure was higher in control cake than FDS powder incorporated cake and ODS powder incorporated cakes.

- FTIR spectra of ingredients and cake were analysed and the functional interaction that took place during the formulation and processing of cakes were examined. Changes in protein structure in the cakes as a result of exposure to higher temperature during baking were evident from the analysis.
- Storage stability of cakes incorporated with both types of surimi powder were analyzed by estimating TBARS value, peroxide value, free fatty acid value and microbial quality during their storage period. All the biochemical stability parameters were within the acceptable limits up to 28 days and the microbial parameters were within the acceptable limits up to 30 days.
- The sensory evaluation of control cake, cake incorporated with FDS powder and that incorporated with ODS powder were estimated during storage and the results revealed that the organoleptic quality of the control cake decreased during storage and the scores for overall acceptability decreased from 8.87 ± 0.35 on the 0th day to 5.67 ± 0.48 on the 28th day. The organoleptic quality of the cake incorporated with FDS powder decreased during storage and the scores for overall acceptability decreased from 8.60 ± 0.50 on the 0th day to 4.60 ± 0.72 on the 28th day. The organoleptic quality of the cake incorporated with ODS powder decreased during storage and the scores for overall acceptability

decreased from 8.63 ± 0.49 on the 0th day to 4.73 ± 0.78 on the 28th day.

The shelf lives of cakes incorporated with both types of surimi powder were 21 days.

The obtained results showed the supplementation of surimi powder into flour used for making bakery products at level up to 10% improved the nutritional parameters of the final bakery products. Moreover, inclusion of oven dried surimi powder in bakery products have almost similar acceptability as compared to bakery products incorporated with freeze dried surimi powder. Therefore, from the present study, it is evident and concluded that the utilization of dried surimi powder in food products for fortification, especially of the bakery products up to the concentration of 10% can be recommended for commercial production and these products can be marketed domestically in the initial stage. Furthermore, surimi powder can be used to develop new and varied food products of different types for the improvement of nutritional quality especially targeting the young aged consumers including children who hesitate to consume fish.

VII. REFERENCES

- Abraha, B., Mahmud, A., Admassu, H., Tsion, H.B.M., Xia, W., Yang, F., 2018a. Production of Biscuit from Chinese Sturgeon Fish Fillet Powder (*Acipeneser sinensis*): A Snack Food for Children. *Journal of Aquatic Food Product Technology*. DOI: 10.1080/10498850.2018.1533906
- Abraha, B., Mahmud, A., Admassu, H., Yang, F., Tsighe, N., Girmatsion, M., Xia, W., Magoha, P., Yu, P., Jiang, Q., and Xu, Y., 2018b. Production and Quality Evaluation of Biscuit Incorporated with Fish Fillet Protein Concentrate. *J Nutr Food Sci*. 8, 744.doi: 10.4172/2155-9600.1000744
- Adeleke, R., Odedeji, J.O., 2010. Acceptability Studies on Bread Fortified with Tilapia Fish Flour. *Pakistan Journal of Nutrition*. 9(6), DOI: 10.3923/pjn.2010.531.534
- Agrahar-Murugkar, D., Gulati, P., Kotwaliwale, N., Gupta, C., 2015. Evaluation of nutritional, textural and particle size characteristics of dough and biscuits made from composite flours containing sprouted and malted ingredients. *Journal of Food Science and Technology*, 52, 5129-5137.
- Ahlborn, G.J., Pike, O.A., Hendrix, S.B., Hess, W.M., Huber, C.S., 2005. Sensory, Mechanical, and Microscopic Evaluation of Staling in Low-Protein and Gluten-Free Breads. *Cereal Chemistry*. 82, 328-335.
- Ahmad, B.S., Talou, T., Straumite, E., Sabovics, M., Kruma, Z., Saad, Z., Hijazi, A., Merah, O., 2018. Protein Bread Fortification with Cumin and Caraway Seeds and By-Product Flour. *Foods* (Basel, Switzerland), 7(3), 28.

- Akubor, P., 2003. Functional properties and performance of cowpea/plantain/wheat flour blends in biscuits. *Plant Foods Human Nutr.* 5, 81–88.
- Alemán, M., Bou, R., Tres, A., Polo, J., Codony, R., Guardiola, F., 2015. Oxidative stability of a heme iron-fortified bakery product: Effectiveness of ascorbylpalmitate and co-spray-drying of heme iron with calcium caseinate. *Food Chemistry*. 196, 567–576.
- Ali, R., Saeed, S.M.G., Ali, S.A., Sayed, S.A., Ahmed, R., Mobin, L., 2018. Effect of black gram flour as egg replacer on microstructure of biscuit dough and its impact on edible qualities. *Journal of Food Measurement and Characterization*. 12(3), 1641–1647.
- Alyas, S.A., Abdullah, A., Idris, N.A., Top, A.G.M., 2006. Evaluation of storage stability of yellow cake made with red palm fat. *Journal of Oil Palm Research. Special issue*, 81-86.
- Anonymous, 1990. Approved Methods. American Association of Cereal Chemists, St. Paul, Minnesota.
- AOAC., 1995. Official methods of analysis, 16th edn. Association of Official Analytical Chemists, AOAC International, Arlington, VA, USA.
- APHA, 1976. Compendium of methods for the microbiological examination of foods, Speck M.L. (Ed), APHA, New York.
- Baiano, A., Viggiani I., Terracone, C., Romaniello.R., Del Nobile M.A., 2015. Physical and sensory properties of bread enriched with phenolic aqueous extracts from vegetable wastes. *Czech J. Food Sci.* 33, 247–253.

- Balarabe, M.M., Mohammed, S.S.D., Orukotan, A.A., 2017. Physico-chemical analysis and sensory evaluation of bread produced using different indigenous yeast isolates. *Science World Journal*.12 (1), 33-37.
- Bastos, S.C., Tavares, T., Pimenta, M.E.S.G., Leal, R., Fabrício, L.F., Pimenta, C. J., Nunes, C.A., Pinheiro, A.C., 2014. Fish filleting residues for enrichment of wheat bread: chemical and sensory characteristics. *Journal of food science and technology*. 51(9), 2240-5.
- Belitz, H-D., Grosch, W., Schieberle, P., 2009. Food Chemistry. London: Springer
- Beloved D.M., Makimilua, T.B., Peace, A., Kwaku, A.J., Zeppora, A.K., 2012. Assessing the proximate composition and shelf-life of different brands of bread on the market in Ghana. *Annals. Food Science and Technology*. 13(1), 29-36.
- Bhise, S., Kaur, A., 2014. Baking quality, sensory properties and shelf life of bread with polyols. *Journal of food science and technology*. 51(9), 2054-61.
- *Caruso, M.C., Galgano, F., Colangelo, M.A., Condelli, N., Scarpa, T., Tolve, R., Favati, F., 2016. Evaluation of the oxidative stability of bakery products by OXITEST method and sensory analysis. *European Food Research and Technology*. 243(7), 1183–1191.
- Centenaro, G.S., Feddern, V., Bonow, E.T., Myriam, S.M., 2007. Enriquecimento de pão com proteínas de pescado. *Ciênc.Tecnol.Aliment*. [online], (27)3, 663-668. (Accessed on 24.3.2019)
- Central Marine Fisheries Research Institute, CMFRI., 2017. Available at www.cmfri.org.in (Accessed on 28.02.2019)

- Chang R.C., Li C.Y., Shiau S.Y., 2015. Physico-chemical and sensory properties of bread enriched with lemon pomace fiber. *Czech J. Food Sci.*33, 180–185.
- Chavan, B. R., Basu, S., Kovale, S. R., 2008. Development of edible texturized dried fish granules from low-value fish croaker (*Otolithus argenteus*) and its storage characteristics. Chiang Mai University. *Journal of Natural Sciences* 7, 173-182.
- Chuapoe huk, P., Raksakulthai, N., Worawattanamateekul, W.,2001. Process development of fish sausage.*International Journal of Food Properties*..4(3), 523-529, DOI: 10.1081/JFP-100108653
- Chung, Y., Ho, M., Chyan, F., Jiang, S., 2000. Utilization of freeze dried mackerel (*Scomber australasicus*) muscle proteins as a binder in restructured meat. *Fisheries Sci.*66, 5–130.
- Central Marine Fisheries Research Institute, Cochin. 2018. Annual Report 2017-2018. Cochin, India: CMFRI.
- Damodaran, S., 1996. Amino acids, peptides and proteins. In: Fennema, O. R. (Ed), Food Chemistry, 3rd edn, Marcel Dekker Inc, New York. p. 321–429.
- Das, R., Biswas, S., Banerjee, E.R., 2016. Nutraceutical-prophylactic and therapeutic role of functional food in health.*J. Nutr. Food Sci.* 6, 527.
- Datta, AK., Sahin,S., Sumnu, G., Keskin, S.O., 2006. Porous media characterization of breads baked using novel heating modes. *Journal of Food Engineering*, 79, 106–116.

- Demirkol, O.S., 2007. Investigation of physical properties of different cake formulations during baking with microwave and infrared-microwave combination. Ph.d. Thesis submitted to the Middle East Technical University, Çankaya/Ankara, Turkey.
- Ducept, F, De-Broucker, T., Souliè, J.M., Trystram, G., Cuvelier, G., 2012. Influence of the mixing process on surimi seafood paste properties and structure. *J. Food Eng.* 108 (4), 557-562.
- El-fadaly, Husain, El-Kadi, Sherif, S., El-Gayar, 2017. Microbiological examination for some chocolate cakes samples. *Journal of Environmental Science, Mansoura University.* 45, 1-24.
- El-kholie, E.M., Mohammed, A.T., Abdelreheem, Khader, S.A., 2014. Utilization of common carp fish surimi in baby food products. *African Journal of Agricultural Research.* 9(30), 2332-2338.
- El-Sharnouby, G., Aleid, S., Al-Otaibi, M., 2011. Nutritional Quality of Biscuit Supplemented with Wheat Bran and Date Palm Fruits (*Phoenix dactylifera* L.). *Food and Nutrition Sciences.* (3) 3, 322-328.
- Ernst, J., Ettyang, G., Neumann, G.C., 2014. High-nutrition biscuits to increase animal protein in diets of HIV-infected Kenyan women and their children: A study in progress. *Food and Nutrition Bulletin.* 35 (4), 198-204.
- Eurofins, 2019. <https://www.eurofinsus.com/food-testing/testing-services/stability-and-shelf-life/rancidity/> (assessed on 10.3.2019)

- Fang S.E., 2008. Physico-chemical and organoleptic evaluations of wheat bread substituted with different percentage of pumpkin flour (*Cucurbita moschata*). Master's thesis submitted to the University Sains Malaysia, Penang
- Filipčev, B., Šimurina, O., Bodroža-Solarov, M., Vujakovic, M., 2011. Evaluation of physical, textural and microstructural properties of dough and honey biscuits enriched with buckwheat and rye. *Chemical Industry and Chemical Engineering Quarterly*. 17. 291-298. 10.2298/CICEQ110204014F.
- Florence, S.P., Urooj, A., Asha, M.R., Rajiv, J., 2014. Sensory, physical and nutritional qualities of cookies prepared from Pearl Millet (*Pennisetum typhoideum*). *J. Food Process. Technol.* 5, 377.
- Foegeding, A., Davis, J.P., 2011. Food protein functionality: A comprehensive approach. *Food Hydrocolloids* 25, 1853-1864.
- Food and Agriculture Organization of the United Nations, World Health Organization and United Nations University, 1985. Energy and protein requirements: report of a Joint FAO/WHO/UNU Expert Consultation [held in Rome from 5 to 17 October 1981]. Geneva : World Health Organization.
- Foodprocessingbazaar., 2017. Bakery industry - Present and future prospects. <http://www.foodprocessingbazaar.com/articles/99-bakery-industry-present-and-future-prospects.html> (accessed on 07.10.2018)
- Foot, R., 1996. Prepare and cook basic hot and cold desserts. In: Thorne N (2nd Ed.), Food preparation and cooking: cookery units - student guide. Nelson Thornes Ltd., Delta Place, 27 Bath Road, Cheltenham, GL53 7th, United Kingdom, 92-115.

- Giannou, V., Tzia, C., 2007. Frozen dough bread: quality and textural behavior during prolonged storage prediction of final product characteristics. *Journal of Food Engineering*. 79: 929-934.
- Giusti, A., Armani, A., Sotelo, C.G., 2017. Advances in the analysis of complex food matrices: Species identification in surimi-based products using Next Generation Sequencing technologies. *PLOS ONE*, 12(10), e0185586. doi:10.1371/journal.pone.0185586 .
- Gogoi, B.K., Oswalt, A.J., Choudhury, G.S., 1996. Reverse screw elements and feed composition effects during twin-screw extrusion of rice flour and fish muscle blends. *J. Food. Sci.* 61(3), 590-595.
- Graven, A.R., 2017. *Developing enzymes which can remove fish odour.* <https://uni.no/en/news/2017/12/14/developing-enzymes-remove-fish-odour/> (accessed on 28.2.2019)
- Green, D., Lanier, T.C., 1985. Fish as the soybean of the sea. In International Symposium on Engineered Seafood Including Surimi.42-52
- Guo, X., Shi, L., Xiong, S., Hu, Y., You, J., Huang, Q., Yin, T., 2018. Gelling properties of vacuum-freeze dried surimi powder as influenced by heating method and microbial transglutaminase. *LWT*. 99, 105-111 doi:10.1016/j.lwt.2018.09.050.
- Hafez, A.A., 2012. Physico-Chemical and Sensory Properties of Cakes Supplemented with Different Concentration of Marjoram. *Australian Journal of Basic and Applied Sciences*.6, 463-470.

- Henchion, M., Hayes, M., Mullen, A.M., Fenelon, M., Tiwari, B., 2017. Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods*. 6, 53.
- Ho, L.H., Aziz, N.A.A., Bhat, R., Azahari, B., 2014. Storage studies of bread prepared by incorporation of the banana pseudo-stem flour and the composite breads containing hydrocolloids. *CyTA . Journal of Food* 12 (2), 141-149.
- Hoda, M., El Gezery, 2017. Chemical and nutritional comparison between school's biscuits and supplemented biscuits with another protein sources. *J. Am. Sci.* 13(12), 84-89.
- Höglund, E., Albinsson, A., Stuhr-Olsson, G., Signäs, M., Karlsson, C., 2017. Protein and energy enriched muffins designed for nutritional needs of older adults. *Nutri Food SciInt J*. 2(4): 555592. 003 .
- Homann, A.M., Ayieko, M.A., Konyole, S.O., Roos, N., 2017. Acceptability of biscuits containing 10% cricket (*Acheta domesticus*) compared to milk biscuits among 5-10-year-old Kenyan schoolchildren. *Journal of Insects as Food and Feed*. 3.1-10.
- Hoojjat, P., Zabik, M.E., 1984. Sugar snap cookies prepared with wheat navy bean-sesame seed flour blends. *Cereal Chem*. 61(1), 41-44.
- Huda N, Abdullah A, Mustapha W.A.W., Babji AS., 2003. Penggunaan tepung surimi dalam formulasi bebola ikan. *Sains Malaysiana*. 32, 27–38.

- Huda, N., Abdullah, A., Babji, A.S., 2000a. Effects of Cryoprotectants on functional properties of dried lizard fish (Sauridatumbil) surimi. *Malaysian Applied Biology*. 29(1 & 2), 6-9.
- Huda, N., Abdullah, A., Babji, A., 2000b. Nutritional quality of surimi powder from threadfin bream. *Malaysian Journal of Muscle Food*. 11, 99-109.
- Huda, N., Abdullah, A., Babji, A., 2001. Substitution of Tapioca Flour with Surimi Powder in Traditional Crackers (Keropok Palembang).16th Scientific Conference Nutrition Society of Malaysia, 24-25 March 2001, Kuala Lumpur.
- Huda, N., Abdullah, A., Babji, A. S., 2001a. Functional properties of surimi powder from three Malaysian marine fish. *Intl.J. Food Sci. Tech*. 36(4), 401-406.
- Huda, N., Ikhlas, B., Ismail, N., 2009. The effect of different ratios of Dory fish to tapioca flour on the linear expansion, oil absorption, colour and hardness of fish crackers. *Journal of International Food Research*. 16, 159-165.
- Hussain, S., Al-Oulabi, R., 2009. Studying the Possibility of Preparing an Egg-Free or Egg-Less Cake. *International Journal of Engineering & Technology*. 1, 324-329.
- Hwang, H.J., Choi, S.Y., Lee, S.C., 2013. Preparation and Quality Analysis of Sodium-Reduced Fried Fish Cakes. *Preventive Nutrition and Food Science*. 18(3), 222-225.
- Ijah, U.J.J., Auta, H.S., Aduloju, M.O., Aransiola, S.A., 2014. Microbiological, Nutritional, and Sensory Quality of Bread Produced from Wheat and Potato Flour Blends. *International Journal of Food Science*. Article ID 671701, 6 pages, <https://doi.org/10.1155/2014/671701>.

- Jacobs, M.B., 1958. The chemical analysis of foods and food products. Van Nostrand Reinhold Company., New York, UK. 393-394.
- Jain, P., Sangita, B., Karuna, S., 2017. Effect of nutritional, physiochemical and sensory properties on the development of bread with incorporation of wheat grass powder. *International Journal of Food Science and Nutrition*. 2. 109-114.
- Jaiswal, R.K., Pathak. V., Goswami. M., Mandal, T., 2015. Texture profile analysis of chicken meat biscuits at ambient temperature in aerobic packaging. *Veterinary practitioner*. 16. 124-125.
- Jensen, S., Oestdal, H., Clausen, M.R., Andersen, M.L., Skibsted, L.H., 2011. Oxidative stability of whole wheat bread during storage. *LWT - Food Science and Technology*. 44(3), 637–642.
- Jeyakumari, A., Ninan, G., Joshy, C.G., Parvathy, U., Zynudheen, A.A., Lalitha, K.V., 2016. Effect of chitosan on shelf life of restructured fish products from pangasius (*Pangasianodon hypophthalmus*) surimi during chilled storage. *Journal of Food Science and Technology*. 53(4), 2099–2107. doi:10.1007/s13197-016-2174-3 .
- Jongsutjarittam, N., Charoenrein, S., 2013. Influence of waxy rice flour substitution for wheat flour on characteristics of batter and freeze-thawed cake. *Carbohydrate Polymers*. 97(2), 306–314.
- Kârkliòa, D., IlgaGedrovica, MarinaReca, MaijaKronberga., 2012. Proceedings of the, Section B. 3 (678), 113–116.

- Kaur, A., Kochhar, A., 2017. Sensory and Proximate Analysis of Value Added Bakery Products Using Bael (*Aegle marmelos*) and Stevia Powder. *Int. J. Curr. Microbiol. App. Sci.* 6(12), 3749-3760.
- Ke, P.J., Woyewoda, A.D., Regier, C.W., Ackman, R.G., 1976. An improved titrimetric method for determination of free fatty acids in fish oils. *Environment Canada.* 6, 1-6.
- Khalifa, I., Barakat, H., El-Mansy, H.A., Soliman, S.A., 2015. Physico-Chemical, Organolytical and Microbiological Characteristics of Substituted Cupcake by Potato Processing Residues. *Food and Nutrition Sciences.* 6, 83-100.
- Kok, T. N., Park, J.W., 2007. Extending the shelf life of set fish ball. *Journal of Food Quality.* 30(1), 1–27.
- Ktenioudaki, A., O'Shea, N., Gallagher, E., 2013. Rheological properties of wheat dough supplemented with functional by-products of food processing: Brewer's spent grain and apple pomace. *Journal of Food Engineering.* 116, 362–368.
- Kumar, P., Chatli, M.K., Mehta, N., Malav, O.P., Verma, A.K., Kumar, D., 2015. Quality Attributes and Storage Stability of Chicken Meat Biscuits Incorporated with Wheat and Oat Bran. *Journal of Food Quality.* 39, 649-657.
- Latif, A., Masud, T., Khan, H., Nuzbaanjam, 2005. Quality improvement and shelf life extension of bread. *J. Agri. Soc. Sci.* 1(2), 2005
- Lee, C.M.V., Lampila, L.E., Crawford, D.L., 2006. Yield and composition of surimi from pacific whiting (*Merluccius productus*) and the effect of various protein additives on gel strength. *Journal of Food Science.* 55, 83 - 86.

- Lempek, T.S., Vilásia G.M., Prentice, C., 2007. Rheology of Surimi-Based Products from Fatty Fish Underutilized by the Industry. *Journal of Aquatic Food Product Technology* 16(4) 27-44.
- *Liapis, A. I., 1987. Freeze drying. In: Mujumdar, A. S., (Ed). Handbook of Industrial Drying. Marcel Dekker Inc. New York. p. 295-376.
- Majumdar, A., Chowdhury, Supratim, Nath, Swarnadyuti, Mondal, K., 2017. Physico-chemical properties and proximate composition of surimi powder from Tilapia (*Oreochromis mossabicus*). *Journal of Agricultural Engineering and Food Technology*. 4, 38-41.
- Mamat, H., Hill, S.E., 2012. Effect of fat types on the structural and textural properties of dough and semi-sweet biscuit. *Journal of food science and technology*. 51(9), 1998-2005.
- Marina, A.M., Nurhanan, A.R., Ishak, W., Rosli, W., Ain, O.N., (2016). Physical properties and microstructure of butter cake added with *Persea americana* puree. *Sains Malaysiana*. 45(7), 1105-1111.
- Marine Products Export Development Authority, MPEDA., 2018. Available at www.mpeda.gov.in (accessed on 28.02.2019).
- Matsuda, Y., 1981. Protein denaturation during freeze drying of carp myofibrils. *Bulletin of Japanese Society of Scientific Fisheries*. 47(7), 813-815.
- Matsumoto, J. J., Noguchi, S. F., 1992. Cryostabilization of protein in surimi. In: Lanier, T. C., Lee, C. M., (Eds). Surimi technology, Marcel Dekker Inc, New York. p. 357-388.

- Meenachi, B., 2016. Preparation of fish protein powder from low value freshwater fish. Master's thesis submitted to the Tamil Nadu Fisheries University, Nagapattinam.
- Menon, A.S., Mujumdar, A.S., 1987. Drying of solids: Principles, Classification and Selection of Dryers. In: Mujumdar, A.S., (Ed). Handbook of Industrial Drying. Marcel Dekker Inc. New York. pp 3-46.
- Miller, R., Groninger, H.S., 1976. Functional properties of enzyme modified acylated fish protein derivatives. *J. Food. Sci.*41,268-272.
- Ministry of Agriculture., 2009. Malaysia: Per capita consumption of livestock products 1999-2008.
- *Mira, de-N., Marquez, L., Maria, U., 2005. Avaliação da composição centesimal, aminoácidos e mercúriocontaminante de surimi. *Food Science and Technology*, 25(4), 665-671.
- Mishra M.L., Sood, S., Shukla, U.N., 2018.Standardization, Development and Proximate Composition of Baked Value Added Products by Using Indian Horse Chestnut (*Aesculusindica*) Flour.*Int.J.Curr.Microbiol.App.Sci.* 7(02), 1449-1458.
- Mohamed, G.F., Sulieman, A.M., Soliman, G.N., Bassiuny, S.S., 2014. Fortification of biscuits with fish protein concentrate.*World Journal of Dairy and Food Sciences.* 9(2), 242-249.
- Monteiro, M.L.G., Mársico E.T., Junior, S., Deliza R, Oliveira, D., Junior, C., 2018. Tilapia-waste flour as a natural nutritional replacer for bread: A consumer perspective. *PLoS ONE*.13(5): e0196665.

- Morrissey, M.T., Tan, S.M., 2000. World resources of surimi. *In: J. Park (Ed.), Surimi and Surimi Seafood*, Marckel Decker Inc., New York: 1-21.
- Movahhed, K.M., Mohebbi, M., Koocheki, A., Milani, E., 2016. The effect of different emulsifiers on the eggless cake properties containing WPC. *J Food Sci Technol.* 53(11), 3894-3903.
- Niki, H., Matsuda, Y., Suzuki, T., 1992. Dried Forms of Surimi. *In: Lanier TC, Lee CM (eds) Surimi technology*. Marcel Dekker Inc, New York, 209–244
- Nikkila, M.E., Constantinides M.S., Meade, L.T., 1976. Supplementation of Arabic and Indian breads with fish protein concentrate. *Journal of agricultural and food chemistry.* 24. 1144-7.
- Odedeji, J.O., Ojo, A., Arogundade, L.A., Oyeleke, G.O., 2014. Proximate composition and consumers acceptability of bread produced from blends of soy-cheese and wheat flour. *Journal of Environmental Science, Toxicology and Food Technology.* (IOSR-JESTFT) e-ISSN: 2319-2402,p- ISSN: 2319-2399. 8(2), II, 41-44
- Okada, M., 1992. History of surimi technology in Japan. *In: Lanier, T.C. and Lee, C.M. (ed.). Surimi Technology*. New York: Marcel Dekker Inc. 3–21.
- Osuna, M.B., Romero, C.A., Romero, A.M., Judis, M.A., Bertola, N.C., 2018. Proximal composition, sensorial properties and effect of ascorbic acid and α - tocopherol on oxidative stability of bread made with whole flours and vegetable oils. *LWT.* 98, 54–61. doi:10.1016/j.lwt.2018.08.012

- Oyetayo, V.O., Oyedeji, R.R., 2017. Proximate and Mineral Composition of Bread Fortified with Mushroom (*Plerotus ostreatus* and *Calocybe indica*). *Microbiology Research Journal International*. 19(4), 1-9.
- Ozogul, Y., Boga, E.B., Tokur, B., Ozogul, F., 2011. Changes in biochemical, sensory and microbiological quality indices of common Sole (*Solea solea*) from the Mediterranean Sea during ice storage. *Turk. J. Fisheries Aqua. Sci.* 11, 243-251.
- Park, J.W., Lin, T.M.J., 2005. Surimi: Manufacturing and Evaluation. In: Surimi and Surimi Seafood, Park, J.W. (Ed.). 2nd Edn., CRC Press, Florida, ISBN: 0824726499, pp: 33-106.
- Parvathy, U., Sajan, G., 2011. Influence of cryoprotectant levels on storage stability of surimi from *Nemipterus japonicus* and quality of surimi based products. *J Food SciTechnol*.1–6.doi: 10.1007/s13197-011-0590-y
- Pfister, F., 2013. The history of baking and pastry cooking. <https://www.webcitation.org/6E9xsAyxZ?url=http://www.pfisterconsulting.com/history.htm#Start> (accessed on 12.2.2019)
- PHLSG., 2008. The microbiological quality of ready-to-eat food samples at the point of sale. (Public Health Laboratory Service Guidelines). Brough Council. 134p.
- Pi, T.H., Shiau, C.Y., Chang, C.J., Sung, W.C., 2017. Studies on the development and quality of fish chiffon cake and its storage stability. *Journal of Aquatic Food Product Technology*. DOI: 10.1080/10498850.2017.1364820
- Pourfarzad, A., HabibiNajafi, M.B., Khodaparast, M.H., Khayyat, M.H., 2015. Serish inulin and wheat biopolymers interactions in model systems as a basis for

- understanding the impact of inulin on bread properties: a FTIR investigation. *Journal of Food Science and Technology*. 52(12),7964–7973.doi:10.1007/s13197-015-1939-4
- Prajapati, R., Chandra, S., Samsher., Chauhan, N., Singh, G.R., Kumar, S., 2015. Effect of incorporation of flours on the functional properties of composite flours. *South Asian Journal of Food Technology and Environment*. 1(3&4), 233-241.
- Ratti, C., 2008. Freeze and vacuum drying of foods. In: Chen, X.D., Mujumdar, A.S., (Eds.). *Drying Technologies in Food Processing*. Blackwell Publishing Ltd, Singapore. pp. 225–251.
- Ravimannan, N., 2016. Study on microbial profile of bread during storage. *Int. J. Adv. Res. Biol. Sci.* 3(9), 60-63.
- Ravimannan, N., Sevel, P., Saarutharshan, S., 2016. Study on fungi associated with spoilage of bread. *Int. J. Adv. Res. Biol. Sci.* 3(4), 165-167.
- Rebecca, L.J., Seshiah, D., Sharmila, 2016. Fortification of Cupcakes with Cereals and Pulses. *International Journal of Novel Research in Life Sciences*. 3(3), 1-6
- Rozeegar, M.H., Shahedi, M., Keramet, J., Hamdami, N., Roshanak, S., 2014. Effect of coated and uncoated ground flaxseed addition on rheological, physical and sensory properties of Taftoon bread. *Journal of Food Science and Technology*. 52(8), 5102–5110.doi:10.1007/s13197-014-1596-z

- Sampels, S., 2014. Towards a more sustainable production of fish as an important source for human nutrition. *Journal of Fisheries & Livestock Production*. 2, 119.
- Santana, P., Huda, N., Yang, T. A., 2013. Physicochemical properties and sensory characteristics of sausage formulated with surimi powder. *Journal of food science and technology*, 52(3), 1507-15.
- Santana, P., Huda, N., Yang, T.A., 2012. Technology for production of surimi powder and potential of applications. *International Food Research Journal*. 19(4), 1313-1323.
- Saranraj, P., Geetha M., 2012. Microbial Spoilage of Bakery Products and Its Control by Preservatives. *International Journal of Pharmaceutical & Biological Archives*. 3(1), 38-48
- Shaviklo, G. R., Olafsdottir, A., Sveinsdottir, K., Thorkelsson, G., Rafifour, F., 2010a. Quality characteristics and consumer acceptance of high fish protein puffed corn fish snack. *J. Food.Sci.Technol*. 48 (6).668-676.
- Shaviklo, G. R., Thorkelsson, G., Arason, S., Kristinsson, H.G., Sveinsdottir, K. 2010 b. The influence of additives and drying methods on quality attributes of fish protein powder made from saithe (*Pollachius virens*). *Journal of the Science of Food and Agriculture*. 90, 2133-2143.
- Shaviklo, G.R., Thorkelsson, G., Arason, S., Sveinsdottir, K., 2010c. Characteristics of freeze-dried fish protein isolated from saithe (*Pollachius virens*). *J. Food.Sci.Technol*.49 (3), 309 -318.

- Shaviklo, G. R., Thorkelsson, G., Sveinsdottir, K., Pourreza, F., 2011. Studies on processing, consumer survey and storage stability of ready-to-reconstitute fish cutlet mix. *J. Food. Sci. Technol.* 50(5), 900-908.
- Shyu, Y.S., Sung, W.C., 2010. Improving the emulsion stability of sponge cake by the addition of γ -polyglutamic acid. *Journal of Marine Science and Technology*. 18, (6), 895-900.
- Silky, 2014. Development of high fiber and high protein biscuits by substituting wheat flour with wheat bran and pigeon pea broken flour. Ph.D. thesis submitted to the Jiwaji University, Gwalior.
- Sivam, A.S., Waterhouse, D., Perera, C.O., Waterhouse, G. I. N., 2011. Application of FT-IR and Raman spectroscopy for the study of biopolymers in breads fortified with fibre and polyphenols. *Food Research International*. 50(2), 574–585. doi:10.1016/j.foodres.2011.03.039
- Sivam, A.S., Sun-Waterhouse, D., Perera, C.O., Waterhouse. G.I.N., 2012. Exploring the interactions between blackcurrant polyphenols, pectin and wheat biopolymers in model breads; a FTIR and HPLC investigation. *Food Chem.* Volume 131(3), 802-810
- Skendi, A., Mouselimidou, P., Papageorgiou, M., Papastergiadis, E., 2018. Effect of acorn meal-water combinations on technological properties and fine structure of gluten-free bread. *Food Chemistry*, 253, 119–126. doi:10.1016/j.foodchem.2018.01.144

- Snack Food & Wholesale Bakery, 2019.
<https://www.snackandbakery.com/topics/6007-bakery-products>. (Accessed on 03.2.2019)
- Soni, N., Kulkarni, A.S., Patel, L., 2018. Studies on development of high protein cookies. *Int. International Journal of Chemical Studies*. 6(6), 439-444
- Sozer, N., Bruins, R., Dietzel, C., Franke, W., Kokini, J.L., 2010, *Improvement of shelf life stability of cakes*. *Journal of Food Quality*. 34, 151-162.
- Stellamaris, K., Martin, M., Crespo, M.V., 2018. Formulation of a Nutrient-Rich Complementary Biscuit for Children Between Eight Months and Fifty Nine Months. *International Journal of Food Science and Biotechnology*. 3(1), 33-39.
- Tacon, A.G.J., Metian, M., 2013. Fish Matters: Importance of Aquatic Foods in Human Nutrition and Global Food Supply. *Reviews in Fisheries Science*. 21, 22-38.
- Tavares, B.O., Silva, E.P., Silva, V.S.N., Júnior, M.S., Ida, E.I., Damiani, C., 2016. Stability of gluten free sweet biscuit elaborated with rice bran, broken rice and okara. *Food Science and Technology*. 36(2), 296–303. doi:10.1590/1678-457x.0083
- Tiimub, B. M., 2013. Proximate Analyses of Three Brands of Bread under Different Storage Conditions Available on the Ghanaian Market. *Food Science and Quality Management*. 12, 23-29.

- Towers. L., 2016. Removing the smell: could odourless fish take off in Japan?
<https://thefishsite.com/articles/removing-the-smell-could-odourless-fish-take-off-in-japan> (accessed on 10.2.2019)
- Toyoda, K., Kimura. I., Fujita, T., Noguchi, S.F., Lee, C.M., 1992. Surimi manufacturing process. In: Lanier TC, Lee CM (eds) Surimi technology. Marcel Dekker Inc, New York, 79–166
- Turan, H., Sönmez, G., 2010. Changes in proximate composition of thornback ray surimi during washing and frozen storage. *Journal of Food Processing and Preservation*. 34, 24-34.
- Unachukwu, M.N., Nwakanma, C., 2015. The fungi associated with the spoilage of bread in Enugu state. *Int. J. Curr. Microbiol. App. Sci.* 4(1), 989-995
- Venturi, F., Sanmartin, C., Taglieri, I., Nari, A., Andrich, G., Terzuoli, E., Donnini, S., Nicolella, C., Zinnai, A., 2017. Development of phenol-enriched olive oil with phenolic compounds extracted from wastewater produced by physical refining. *Nutrients*. 9, 916.
- Verardo, V., Riciputi, Y., Trivisonno, M.C., Marconi, E., Caboni, M.F., 2010. Effect of the addition of air-classified barley flours on the lipid stability of bakery products. *European Food Research and Technology*. 231(2), 309–319.
- Wei, Hu, Wei, Zhang, Yi, X., Zhang, Ping, F., Sun, Qin, S., Liu, Yuan, Changhua, X., 2018. Analysis of protein structure changes and quality regulation of surimi during gelation based on infrared spectroscopy and microscopic imaging. *Scientific Reports*. 8. 10.1038/s41598-018-23645-3.

- Xiong, Y.L., 2004. Muscle proteins, Editor(s): Yada, R.Y., In Woodhead Publishing Series in Food Science, Technology and Nutrition, Proteins in Food Processing, Woodhead Publishing, 100-122, ISBN 9781855737235.
- Yasumatsu, K., Sawada, K., Moritaka, S., Misaki, M., Toda, J., Wada, T., Ishi, K., 1972. Whipping and emulsifying properties of soybean products. *Agricultural and Biological Chemistry*.36, 719-727.
- Yathavamoorthi, R., Sankar, T.V., Ravishankar, C.N., 2012. Effect of Ice Storage on the Characteristics of Common Carp Surimi. *Fishery Technology*. 49: 38 - 44
- Zanardi, E., Ghidini, S., Battaglia, A., Chizzolini, R., 2004. Lipolysis and lipid oxidation in fermented sausages depending on different processing conditions and different antioxidants. *Meat science*. 66, 415-423.
- Zeb, A., Ullah, F., 2016. A simple spectrophotometric method for the determination of thiobarbituric acid reactive substances in fried fast foods. *Journal of Analytical Methods in Chemistry*. 1-5.
- Zhang, Y., Song, Y., Hu, X., Liao, X., Ni, Y., Li, Q., 2012. Effects of Sugars in Batter Formula and Baking Conditions on 5-Hydroxymethylfurfural and Furfural Formation in Sponge Cake Models. *Food Research International*. 49, 439-445.

*Originals not referred.