CHARACTERIZATION OF SELECTED CEREALS AND PULSES FOR THE DEVELOPMENT OF FUNCTIONAL FOODS

THESIS

By

SHILPA
(H-2013-40-002)

Submitted to

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HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA
PALAMPUR – 176 062 (H.P.) INDIA

in

partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY IN HOME SCIENCE
(DEPARTMENT OF FOOD SCIENCE, NUTRITION AND TECHNOLOGY)
(FOOD SCIENCE AND NUTRITON)

2019

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CERTIFICATE – I

This is to certify that the thesis entitled **"Characterization of selected cereals and pulses for the development of functional foods"** submitted in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy (Home Science)** in the discipline of **Food Science and Nutrition** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a bonafide research work carried out by **Ms. Shilpa (Admission No. H-2013-40-007)** daughter of **Smt. Kusum Lata & Shri Jaswant Singh** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

Place : Palampur
Dated : December, 2019

(Dr. Sangita Sood)
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CERTIFICATE- II

This is to certify that the thesis entitled **"Characterization of selected cereals and pulses for the development of functional foods"** submitted by (**Ms. Shilpa, Admission No. H-2013-40-002)** daughter of **Shri Jaswant Singh** to Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Doctor of Philosophy (Home Science)** in the discipline of **Food Science and Nutrition** , has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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ACKNOWLEDGEMENTS

I would like to extend my sincere gratitude of intellectuals as well as the grace of that Almighty. With limitless humility, I would like to praise and thank 'GOD', the merciful, the compassionate, who bestowed me with health, tenacity and courage enough to go through their critical juncture.

I wish there could be really more befitting way than words for acknowledging the indebtedness and to express my loyal and venerable thanks and divulge my deep sense of heartfelt gratitude to my guide Dr. Sangita Sood Professor and Head of the Department of Food Science, Nutrition and Technology for opening my way to new horizons. Her painstaking efforts, praiseworthy guidance, scientific acumen and ever-helping attitude steered the completion of this work.

It is my sole prerogative to place on record my indebtedness and everlasting gratitude to the members of my Advisory Committee specially Dr. Y. S. Dhaliwal Professor (Deptt. of Food Science, Nutrition and Technology) and Dr. Neelam Sharma Professor and Head (Deptt. of Chemistry and Biochemistry), and Dr. Birbal Singh Senior Scientist of, Indian Veterinary Research Institute for their help, innovative guidance and invaluable suggestions during the course of study.

I avail myself of this rare opportunity to express my ecstatic thanks to Dr. Y. S. Dhaliwal, Dean (COHS) and all the teachers of (Deptt. of Food Science, Nutrition and Technology) especially Dr. Farhan Mohiuddin Bhat for their kind cooperation and impeccable guidance during the course of the study.

I emphatically express my venerable thanks to Dr. R. K Agnihotri, Dean, Postgraduate Studies and University Authorities for providing me necessary facilities.

I would also like to express my deep thanks to of Dr. Anil Sood director, and Dr. Mahesh Gupta Senior Scientis (Department of Food and Nutraceuticals), IHBT, Palampur for their timely help which is greatly acknowledges.

Thanks are duly acknowledged as they helped me and co operate, timely help and moral support provided by my senior Shweta Sharma and friends batchmates, especially my junior, Anju Rani,official staff and laboratory staff Mast ram uncle, Bhushan Bhaiya and Anil Bhaiya,

I would be selfish if I do not appreciate the constant inspiration and ever available help of my in – laws, elder sister jiju and niece Paras and Mannat, Mr. Yaman Koundal especially my son Mr. Aarush verma and my husband Mr. Abhishek Verma whose association has always been a boost to me and who always supported me in each and every moment, when and where ever required. Words cannot represent my feeling and the language seems inadequate to express my gratitude and respect to my beloved Mother (Smt. Kusum Lata) and Father (Sh. Jaswant Singh) whose limitless moral support, constant encouragement and lively sentiments transformed my ambition into reality.

A word of appreciation should be credited to Mr. Ajay Walia for their painstaking effort in typing this manuscript and make it such a presentable form. Lastly, I thank one and all related to this work directly or indirectly.

Needless to say all omissions and errors are mine.

Thank you all!!

Place: Palampur

Dated: *(Shilpa)*

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LIST OF ABBREVIATIONS USED

Cm	=	Centimeter
ml	=	Milliliter
g	=	Gram
mg	=	Milligram
µg	=	Microgram
kg	=	Kilogram
rpm	=	Revolution per minute
^{o}C	=	Degree Celsius
Fig.	=	Figure
hr	=	Hour
^{o}B	=	Degree Brix
TSS	=	Total Soluble Solids
%	=	Per cent
@	=	At the rate
KMS	=	Potassium metabisulphite
g/lt	=	Gram per litre
g/ml	=	Gram per milliliter
et al	=	And others
viz.	=	Videlicet
i.e.	=	That is
etc.	=	Et cetera

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Title of the Thesis	:	Characterization of selected cereals and pulses for the development of functional foods
Name of the Student	:	Ms. Shilpa
Admission Number	:	H-2013-40-002
Major discipline	:	Food Science and Nutrition
Minor disciplines	:	(i)Biochemistry (ii) Microbiology
Date of Thesis submission	:	December, 2019
Total pages in Thesis	:	191
Major Advisor	:	Dr. Sangita Sood

ABSTRACT

It's the need of the hour to deliver affordable good quality formulation in a convenient format to ensure nutrition security especially amongst vegetarian populace. Consumers' demand can be addressed by making available cereals: pulses based *ready to eat* products. Cereals and pulses are important crops of Indian dietary as they are enriched with functional components. To characterize and optimize high fiber & low protein formulation, important crops of the State *viz.* oat, pearl millet, sorghum, finger millet, horse gram, chick pea and rice bean were selected. Since consumption of these crops in the form of *ready-to-eat* food as extruded form is becoming a common approach. The selected crops were estimated for their quality traits. Amongst cereals and pulses, oat and chick pea came out to be best as far functional properties are concerned. Oat and horse gram are rich in crude fiber as 5.34 and 5.40 per cent respectively. While finger millet and horse gram bagged lowest values for protein (7.45; 21.28 %) and fat (2.00 & 1.80 %) content respectively. Finger millet attained highest score for Ca (269.54g/100g). Finger millet and chick pea was found to be highest values for saponins (5.29; 4.78). Whereas, maximum value for tannin was calculated in pearl millet (228.00). Oat and rice bean can be consider as an alternative for diabetetic patients' palate as they obtained maximum score (2.69; 2.58%) for resistant starch. All the selected cereals and pulses came under the class of low glycemic index. Although slight decline in proximate, nutritional and sensory composition was observed with the increase in storage period within acceptable limit. Amongst the prepared products *kurkure* have the best storage stability and acceptability during storage period up to 120 days. It is conferred that multigrain formulations can be used for the development of value added products with high nutritional profile which might have great potential in food industry.

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1. INTRODUCTION

In the present scenario, opulence world is forced to deal with new challenges like escalated healthcare costs, longer life expectancy and changes in living manner leading to lifestyle related and metabolic diseases *viz.* diabetes, cardiac diseases, obesity and cancer especially colon cancer. As a result, development of functional foods or nutraceuticals comes into play. The demand of functional food is increasing due to its health benefits. Consumers around the world are becoming more and more health conscious and their interest in healthy eating is shifting towards the potential health benefits of specific foods and food ingredients. Moreover, scientific evidence supports the idea that some of these might have positive effects on our health and well-being, beyond the provision of basic nutritional requirements.

Functional foods are having potentially beneficial components which are either found naturally in food or added as functional ingredients, as include carotenoids, dietary fiber, flavonoids, fatty acid, isothiocyanate, phenolic acid, plant stanols and sterols, ployols, prebiotics, probiotics, phytoestogen, soyprotein, vitamins and minerals. These food components are recognized by health professionals as they play a have a major role in health enhancement.

Cereal and pulses which are the staple food item of Indian dietary are good sources of calories, protein, micronutrients, dietary fiber and resistant starch, coupled with low glycemic index. Due to all these properties they play a vital role in managing all the metabolic diseases. Traditionally, whole grains were consumed but most current foods are derived from refined fractions of cereal and pulse crops. Consumption of processed or refined products may reduce the health benefits of food.

Millets are group of cereal crops, cultivated around the world in diverse topographical conditions, for food and fodder. They are small-seeded with different varieties such as pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), kodo millet (*Paspalum setaceum*), proso millet (*Penicum miliaceum*), foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*) and barnyard millet (*Echinochloa utilis*). Bouis (2000) and Kaur et al. (2012) stated these grains as coarser

cereal besides Maize (*Zea mays*), Sorghum (*Sorghum bicolor*), Oat (*Avena sativa*), and Barley (*Hordeum vulgare*) The total production of millet grains in the world was about 7, 62,712 metric tons and the top producer was India with an annual production of 3,34,500 tons 43.85 per cent (FAO 2012).

Millets can secure India's food and farming in future because of their amazing nutritional properties. Each one of the millets is three to five times nutritionally superior to the widely promoted rice and wheat in terms of macro as well micro nutrients and is not an acid forming food, so it is soothing and easy to digest. In fact, millet is considered to be one of the least allergenic, crops. Moreover, these crops are drought-resistant and the 6th cereal crop in terms of world agriculture production. Also, millets are resistant to pests and diseases, short growing season, and productivity under drought conditions, compared to major cereals (Devi et al. 2011). Therefore, millet grains are now receiving specific attention from many developing countries.

The present investigation **"**Characterization of selected cereals and pulses for the development of functional foods" was done keeping in view all these health promoting properties. The dietary importance of cereal and pulses, functional foods and their role in the management of metabolic diseases, provide an oppertunity to screen out and identify some of high fiber and low protein cultivars of coarser grain and pulses grown in Himachal like Oat (*Avina sativa)*, Finger millet (*Elusine coracana*), Sorghum (*Sorghum bicolor*), Pearl millet (*Pennisetum glaucum*), Rice bean (*Vigna umbellate*), Chick pea (*Cicer arietinum L.*) and Horse gram (*Macrotyloma uniflorum)* for the development of functional foods.

Oat (*Avena sativa*), are unique among the cereals because of their richness in dietary fibers among cereals belongs to the *Poaceae* family (Sangwan et al. 2014). It ranks sixth in world production and almost 96,08,318 hectares of land is under cultivation with total production of 26 Million tonnes (FAO 2017). Although, oat have been cultivated in India mainly for fodder purposes (ICAR 2006), they possess major potential as functional ingredient in food products. In vernacular trem it is known as '*jai*' and '*javi*' in the Indian Subcontinent. It is a self-pollinating hexaploid crop. Due to its rich nutritional composition it is the sixth largest crop growing in the world following wheat, maize, rice, barley and sorghum (Butt et al. 2008).

Finger millet (*Eleusine coracana*), also known as *ragi* is a good source of carbohydrate, protein, dietary fibre and minerals, and an important staple food for

people under low socio- economic group (Sripriya, et al. 1997) and those suffering from metabolic disorders like diabetes and obesity (Mathanghi and Sudha 2012). It is important because of its excellent storage properties and nutritive value (Shashi et al. 2007). Its dietary fibre and mineral content is markedly higher than wheat, rice, and fairly well balanced protein (Ravindran 1991). Finger millet is extensively grown on hilly areas and southern part of India and is widely consumed in the form of dumpling by majority of populace. The crop is thought to have medicinal properties for the treatment of measles, colds, anaemia and diarrhoea (Prasad Sreenivasa, 2004). Finger millet also has a short span of three months, is a day neutral, and thus can be grown more than once a year in certain regions (Barbeau et al. 1993).

Sorghum (*Sorghum bicolor*) is the king of millets and is one of the important food crops in dry lands of tropical Africa, India and China. Nigeria is the largest producer of sorghum in Africa and third largest the world over (USDA 2015). In India, sorghum is one of the staple food crops of many States, and is consumed by majority of people particularly living in the non-irrigated dry land areas with low rainfall. It is cultivated in the semi-arid tropical regions. Sorghum grain is food of the economically weaker sections. It is mainly consumed in the form of unleavened bread (*roti*) and to some extent as popped grains (Vannalli et al. 2008).

Pearl Millet (*Pennisetum glaucum*), also known as *bajra*, is a cereal crop grown in tropical semi-arid regions of the world primarily in Africa and Asia. Pearl millet is the quick growing summer cereal, mainly cultivated in semi arid regions and forms the stable food in Indian subcontinent and in Africa. Bajra is well adapted to production systems characterized by low rainfall (200-600 mm), low soil fertility, and high temperature, and thus can be grown in areas where other cereal crops, such as wheat or maize would not survive. In its traditional growing areas, pearl millet is the basic staple for households in the poorest countries and among the poorest people. It is also one of the most drought resistant crops among cereals and millets (Vanisha et al., 2011). It is the fourth important stable food in India after rice, wheat and sorghum, and nutritionally superior to sorghum and maize. Pearl millet is a rich source of protein, calcium, phosphorus and iron. This crop uses less water per unit of forage production, tolerates both lower and higher soil pH and higher aluminium concentration.

Rice bean (*Vigna umbellata*), belongs to the family a native of South and South-East Asia is a little known pulse in India. Its cultivation is mainly confined to the tribal areas of Eastern and Northern India and to some extent in Orissa and Bihar where it is grown for fodder, green manure, cover crop and food (Bajaj & Malika, 2014). Ricebean (*Vigna umbellata*), like other Vigna species, is a warm-season annual. Grown mainly as a dried pulse, it is also important as a fodder and as a green manure. Ricebean is a neglected legume regarded as a minor food and fodder crop in Nepal and Northern India; it is grown in a range of cropping systems with maize during summer, as a sole crop in the uplands, on rice bunds or in home gardens. It is mainly grown for human consumption, though it is also used for fodder and green manure. The importance of food legumes, especially in the diets of the population of developing nations is well established. Legumes not only add to the variety in human diet, but also serve as an economical source of complementary protein for a large human population in developing countries like India (Kaur, 2015).

Chickpea (*Cicer arietinum L.*), is the third most important legume in the world after dry beans and dry peas (Parthasarathy et al. 2010). Currently, it is grown in more than 50 countries. Originally, it is domesticated in Middle Eastern, African and Asian countries, is the third largest pulse crop in the world (FAO 2011). As a source of vegetable protein, carbohydrates, dietary fiber, vitamins and minerals, the demand for chickpea has increased over the last few years due to its notable nutritional value (Jukanti et al. 2012). The crop is widely cultivated in the Indian sub-continent, Middle East, Eastern Africa, North America and the Mediterranean region (Cho et al., 2002).

The horse gram (*Macrotyloma uniflorum*) commonly known as *kulthi* is a traditional unexploited tropical grain legume and well known for its hardiness, adaptability to poor soil and adverse climatic conditions. Horse gram is largely cultivated, especially in dry areas of Australia, Burma, India and Sri Lanka, mainly for animal feed. It is also used as a vegetable in India and is known as the poor man's pulse crop in southern India. Horse gram is an inexpensive source of protein and is also rich in minerals (Thirukkumar and Sindumathi 2014). It has been identified as one of the potential food sources for the future by the US National Academy of Sciences (1979).

Functional foods are having large dietary potential in the management of metabolic diseases, so in the present study efforts were made for the development of functional foods, by permutation & combination of different crops, keeping in view the therapeutic as well as nutritional values of functional foods, the present study was envisaged with the following objectives:

i. Screening and identification of high fibre and low protein coarser grains/pulses
ii. Optimization of baked and extruded snacks using identified sources
iii. Physicochemical, functional, and quality assessment of developed food matrix
iv. Assessment of sensory and shelf stability of developed products

2. REVIEW OF LITERATURE

To conduct any research, most important part is to understand all the concepts related to the problem**.** The knowledge of scientific literature in the related field of research is of great importance for carrying out research work. Therefore, pertinent research work already done in India as well as in abroad has been reviewed under the following heads and subheads:

2.1 Screening and identification of high fiber and low protein coarser grain/pulses is important for development of products

2.2 Optimization of baked and extruded snacks using identified sources

2.3 Physicochemical, functional and quality assessment of developed food matrix

2.4 Assessment of sensory and self stability of developed products

2.1 Screening of high fiber and low protein coarser grains/pulses is important for the development of quality products. It is done on the bases of following parameters:

2.1.a. Physical evaluation of selected crops

i. Color

Khadka and Acharya (2009) reported the shape of rice bean seed grains as elongated, slightly curved and beaked seeds of variables size.

In the same year, they also observed the colour of rice bean grains of four varieties of Gulmi district and reported as red, brown striped, white to yellowish and greenish to yellowish.

According to sorghum production guidelines (2010) the colour of sorghum seeds may be red, white, yellow, brown and shades.

Tiznado et al. (2012) reported the colour of the chick pea is light cream.

Obilana (2013) reported the colour of pearl millet as white to yellow, grey, brown and purple.

Bhartiya and Kant (2015) studied the physical properties of horse gram and reported the colour of seeds as light red, brown, grey and black.

Later on, in 2017 Ranasingh and Ediriweera studied the medicinal and nutritional values of horse gram and reported the colour of seeds as light red, brown or black.

ii. Shape

Khadka and Acharya (2009) reported the shape of rice bean seed grains as elongated, slightly curved and beaked seeds of variables size.

According to Sorghum production guidelines (2010) the shape of sorghum seed is oval.

Whereas, Tiznado et al. (2012) reported the shape of the chick pea as irregular.

Obilana (2013) studied the nutritional, physico-chemical and sensory characteristics of a pearl millet-based instant beverage powder and reported the shape of pearl millet as drop of a liquid.

Hamdnani et al. (2014) investigated some of physical traits of oat and reported the shape of oat grains as irregular or ellipse whereas, Butt et al. (2008) observed the oat grains as spindle shaped.

Ranasingh and Ediriweera (2017) studied the medicinal and nutritional values of horse gram and reported the shape of seeds as oblong.

iii. Thousand Kernel Weight

Kilickan and Guner (2010) studied the chick pea and reported the thousand kernel weight as 383 g later on in 2014, Garg and Sabharwal evaluated thousand kernel weight of two chick pea genotypes and reported in the range as 114.80±0.66 - 133.80±8.89 g.

According to Siwela et al. (2007) reported thousand kernel weight of twenty two finger millet genotypes ranged from1.77- 3.86 g. Whereas, Nazni and Bhuwaneswari (2015) calculated thousand kernel weight of Finger millet as 2.46±0.005 g.

Sobczyk (2008) reported thousand kernel weight of four cultivars ranged from 24.8 - 36.6 g, Hamdani et al. (2014) also reported thousand kernel weight of oat two genotypes of oat as 36.66±0.001 and 36.51±0.02 g. Whereas, Singh et al. (2015) evaluated five commonly grown hulled oat cultivars and calculated thousand kernel weight in the range of 20.5 - 27.8 g.

Thilagavothi et al. (2015) investigated physical parameter of horse gram and calculated thousand kernel weight as 34.25±1.17g.

Ojediran (2010) reported the value for same in the range of 7.30- 9.47g. whereas, Thilagavothi et al. (2015) recorded the value of same constituent in pearl millet seeds as 8.25±30 g.

Vannolli et al. (2015) evaluated ten genotypes of sorghum for 1000 kernel weight and obtained the results as 25.59 - 41.01 g, whereas, Kenghe and associates (2015) reported thousand kernel weight of sorghum at 10 per cent moisture level as 42.47±1.39 g.

iv. Density

Vannalli et al. (2008) calculated density of sorghum of ten genotypes ranged from 1.14 - 1.22 g/ml, whereas, Boac et al. (2010) reported 1220-1344 kg/m^3 in the same crop. Poomsa-ad and Wiset (2014) reported density of sorghum at 9.06 per cent moisture level as 1257.33±9.86 kg/m^3 and Keghe et al. (2015) obtained density in sorghum grains at slightly high level of moisture i.e. 10.94 per cent 1147.1±0.96 kg/m^3

According to Swami and Swami (2010) density of finger millet increased linearly from 1120 - 1130 kg/m^3, whereas Gull et al. (2015) reported 1.36±0.09g/ml density of finger millet as moisture content increased from 13.00 - 47.93 per cent.

Boac (2010) reported density of oat as 950-1397 kg/m^3 whereas, Hamdnani and colleagues 2014 reported density of oat as 339.50 -335.00 kg/m^3

Kilickan and Guner (2010) reported density of Chick pea as 1390±0.128 kg/m^3 Knife and associates in the year (2015) evaluated density in three cultivars of chick pea and found in the range of 2.37±0.024 to 2.82±0.71 g/ml.

Jain et al, a team of pioneer scientists in 2012 reported density of horse gram of two varieties as 0.51 and 0.47 g/ml. whereas; Bhokre and Joshi (2015) made an attempt to analyze density of horse gram 1.18g/ml.

Obilana in 2013 investigated pearl millet seeds in terms of physical parameters and reported density of pearl millet seed 1.6g/cm^3 whereas; Mamta (2015) reported the value for same parameters in two varieties as 0.02±0.01 g/ml. In the same year, Gull and his team reported the density of pearl millet as 1.69±0.29 g/ml.

v. Bulk density

Olosunde et al. (2014) reported as 0.75±0.11 g/cm^3, Poomsa-ad and Wiset (2014) reported 9.06 per cent moisture level as 815.40±3.32 kg/m^3, whereas, Kumari and Kailppan (2011) stated 0.81±0.1 g/cm^3 whereas, Kenghe et al. (2015) reported bulk density of sorghum as 775.05±4.09 kg/m^3.

Swami and Swami (2010) reported bulk density 709-715 kg/m^3 which was increased linearlly with the increase of moisture content from 13.0 to 47.9 per cent and Nazni and Bhuwneswari (2015) reported bulk density 0.70±0.01 g/ml, whereas in the same year, Gull et al. also reported bulk density of finger millet as 0.67±0.02 g/ml.

Ojedrian et al. (2010) evaluated bulk density of pearl millet of two varieties and reported as 811.4 at 10 per cent moisture level. Thilogavathi et al. (2015) reported bulk density of pearl millet as 1.75±0.01w/v.

Kilickan and Guner (2010) reported bulk density in chick pea as 741.50±0.445 kg/m^3. Eissa et al. (2010) reported bulk density at 11.06 per cent moisture level as 730.05±1.84 kg/m^3 and Shanbzi (2011) recorded bulk density of chick pea at 9.21 per cent moisture level as 835.55 kg/m^3.

Boac et al. (2010) reported bulk density in oat as 412-576 g/m^3. In later years, Singh and team members (2015) also made an effort to calculate bulk density in five varieties of oat and reported in the range of 0.732-0.770 g/ml.

Thilogavati et al. (2015) stated the bulk density in horse gram as 1.53±0.01 w/v whereas, Bhokre and Joshi (2015) reported bulk density in the same crop as 0.78 g/ml.

vi. Porosity

According to Swami and Swami (2010) porosity of finger millet was found to be at 13 per cent moisture level as 36.62 per cent. Gull et al. (2015) reported porosity of finger millet as 50.40±4.39 per cent.

Kilicam and Guner (2010) calculated porosity in chickpea as 46.50±0.392 per cent subsequently Eissa et al. reported the values 11.06 per cent moisture level as 44.13±0.49 per cent and according to Shahbzi (2011) reported porosity of chickpea at 9.21 per cent moisture level as 42.75 per cent.

Ojediran et al. (2010) reported porosity of two variety of pearl millet at ten per cent moisture level as 15.17±0.33 and 17.8±0.36 per cent. Gull et al. (2015) calculated the values as 67.11±5.26 per cent in the same crop.

Kumari and Kallappan (2011) reported 35.53±1.46 per cent porosity of sorghum. Poomsa-ad and Wiset (2014) reported porosity of sorghum at 9.06 per cent moisture level as 35.15±1.63 per cent and Kenghe et al.(2015) reported porosity at 10.94 per cent moisture level as 35.7±0.05 per cent

According to Hamdani et al. (2014) porosity of two variety of oat reported as 63.12±0.01 and 64.11±0.01 per cent.

2.1.b. Functional Properties of selected crops

Sreerama et al. (2007) made an effort to study the properties of horse gram and reported the values for WSI, WAC,OAC ,FS and FC as water solubility index (7.6±0.5), water absorption capacity (135.8±3.8), oil absorption capacity (74.6±1.8), foaming capacity (45.0±1.8), foam stability (38.0±1.5), emulsion activity (52.6±1.8) and emulsion stability (48.2±0.9) per cent.

Abu- Salem and Abu Arab (2011) studied the functional properties of chick pea and reported water absorption index (1.90±0.02) and water solubility 27.94±3.0 per cent.

According to Thilagavathi et al. (2015) reported the functional properties of pearl millet and established as water absorption capacity and oil absorption capacity as 74.08±1.78 and 85.57±3.00 whereas water absorption and oil absorption index as 8.25 ±0.30, 9.62±0.35 respectively.

Gull et al. (2015) reported functional properties of finger millet as water solubility index (7.73±1.80), foaming capacity (1.96±0.00) and foaming stability (0.97±0.01) ml.

Olosunde et al. (2015) reported the functional properties of sorghum as water absorption capacity 2.49± 0.11, water solubility 2.56±0.23 per cent and oil absorption 0.79±0.17mg oil /g.

Singh et al. (2015) evaluated five varieties of oats and reported functional properties as water absorption capacity ranged from 167-186, oil absorption capacity as 189-222 per cent, foaming capacity 8-22 per cent, emulsion activity and emulsion stability as 41.6-56.9 and 68.1- 73.3 per cent.

2.1.c. Poximate Evaluation of Selected Crops

i. Moisture

Jambamma et al. (2011) reported moisture content in sorghum as 10.51±0.61 per cent, which Poomsa-ad and Viset (2014) evaluated as 9.06 per cent. After a span of year Mahajan and Gupta (2015) reported the slightly higher moisture content in sorghum as 10.74±0.01 per cent.

According to Ren and associates (2012) the moisture content in rice bean was found to be 10.56±0.70 per cent later on in 2015 Kaur reported the moisture content on the lower side i.e. 8.60 per cent in the same crop.

In the year 2012, Sreerama et al. reported moisture content 8.2±0.4 per cent in horse gram whereas, Marimuthu and Krishnamoorthi (2013) reported moisture content of horse gram as 6.72±0.03 per cent. Kumar and Sindhumati (2014) evaluated the moisture content in horse gram as 10.60 per cent.

Kumar et al. (2013) reported moisture content in oat as 7.68 per cent. Kaur et al. (2014) reported the moisture content as 10.07±0.06 per cent. Singh et al. (2015) evaluated five varieties of oat and reported the value in the range of 6.7 to 8.2 per cent. Subsequently Ranjan and Saini (2016) reported 8.54±0.01 per cent moisture content in the same crop.

Banusha and Vasanthruba (2013) reported 7.67±0.45 per cent moisture content in pearl millet, Elarence and Vrooj (2014) and Thilagavati et al. (2015) evaluate the moisture content in pearl millet and reported as 9.60±0.82 and 11.46±0.40 per cent respectively.

Chappalwar et al. (2013) reported the moisture content as 8.67 per cent in finger millet. Thereafter Gunashree and team in 2014 also obtained the moisture content in finger millet as 8±0.083 per cent, whereas, Thippeswamy and colleagues (2016) attempted to analyzed the finger millet for the same constituents and reported as 13.57±0.19 per cent.

Shahbazi (2011) reported the moisture content as 9.26 per cent. In the year 2013 Tosh and colleagues evaluated chickpeas for moisture content and reported as 7.03±0.17 per cent, whereas Wani and Kumar (2014) reported 8.40±0.50 per cent moisture in chickpeas.

ii. Ash

Abou Salem and Arab (2011) reported the ash content of chickpea as 3.30±0.02 per cent.

Jain et al. (2012) evaluated two varieties of horse gram and reported ash content as 3.08 and 2.77 per cent respectively. After a year, Marimuthu and Krishnamoorthi (2013) recorded ash content as 2.24±0.24 per cent. Carla along with his team in 2013, attempted to evaluate fourteen genotypes of chickpea and reported the ash content ranged from 3.55-4.77 per cent. Thirukkumar and Sindhumati (2014) reported ash content as 3.30 per cent.

Nkama et al. (2015) reported the ash content as 1.92±0.09 per cent and Azhari et al. (2015) reported ash content a 1.55±0.025 per cent. Knife et al. (2015) also evaluated three cultivars chickpea in their independent work and reported ash content in the range of 2.97±0.02 to 3.43±0.10 percent.

Gunashree et al. (2014) reported the ash content in finger millet as 2.0±0.015 per cent, and Thapliyal and Singh (2015) reported ash content as 2.7 per cent, whereas Thippeswamy et al. (2016) reported ash content as 3.64±0.0 per cent.

Bilal et al. (2014) reported the ash content as 3.04±0.46 per cent. and Singh et al. (2015) evaluated five varieties of oats for ash and the values as ranged from 2.6-3.9 per cent.

Florence and Urooj (2014) also evaluated pearl millet for ash and reported 1.50±0.06 per cent, Thilogavati et al. (2015) reported ash in pearl millet content as 2.9±0.07 per cent. Adeati et al. (2017) attempted to evaluate twenty two varieties of pearl millet for ash and found to be ranged as 1.09-2.72 per cent.

Ren et al. (2012) evaluated rice bean for ash content and reported as 3.26±0.12 per cent. Kaur (2015) analyzed rice bean for ash and reported to be as 5.50 per cent.

iii. Crude Fat

Salem and Arab (2011) reported the fat content in chick pea seeds as 5.62±0.02 per cent. Ghribi et al. (2015) evaluated two cultivars of chick pea and stated the fat content as 5.20±0.87 and 6.54±0.44 per cent respectively. Knife et al. (2015) also evaluated three cultivar of chick pea and reported fat content ranged from 3.77±.30 to 7.01±0.40 per cent.

Kumar et al. (2013) evaluated the fat content of finger millet as 1.98 per cent. Gunashree et al. (2014) reported crude fat content of finger millet as 1.8±0.02 per cent. Thapliyal and Singh (2015) also attempted to calculate fat content in finger millet as 1.5 per cent.

Ren et al. (2012) reported fat content as 8.13±0.27 per cent. whereas, Bajaj (2014) reported the fat content in rice bean varieties in the range of 2.27±0.07 per cent.

Trane et al. (2012) reported the fat content in four varieties of sorghum in the range of 2.30-2.80 per cent. Awadelkareem et al. (2015) evaluated two cultivars of songhum and reported per cent fat as 3.02±0.01 and 2.84±0.07. Nkama et al. (2015) calculated the fat content as 20.38±0.39 per cent.

Anadou et al. (2013) reported 4.86 per cent fat content in pearl millet. Florence and Vrooj (2015) attained the value of fat content in pearl millet as 5.40±0.22. Subsequently, Thillaganathi et al. (2015) calculated as 4.30±0.04 per cent.

Bilal et al. (2014) tested the crude fat content in oat as 5.49±0.76 percent. Kaur et al. (2014) calculated the crude fat content in oat as 6.17±0.03 per cent and Singh et al. (2015) evaluated five crops of oats and reported crude fat content ranged from 4.2-5.3 per cent.

Jain et al. (2012) evaluated the two varieties of horse gram and reported the fat contant as 1.8 and 1.29 per cent respectively. Thilagavathi et al. (2015) reported the fat content in horse gram as 0.82±0.01 per cent whereas, Kamboj and Nanda (2017) obtained the value as 0.50 per cent.

iv. Crude Fiber

Gunashree et al. (2014) reported the crude content of finger millet 3.17±0.02 per cent and Shibairo et al. (2014) evaluated six genotype of finger millet and reported the crude fiber content ranged from 6.53 to 8.59 per cent. Tapliyal and Singh (2015) reported the crude fiber content of finger millet as 3.6 per cent.

Bajaj (2013) evaluated four varieties of rice bean and reported the crude fiber between the range of 3.00±0.35 to 3.60±0.42 per cent. Kaur (2015) reported the crude fiber content of rice bean as 4.65 per cent.

Sharma et al. (2013) analyzed nine cultivar of chick pea and reported result between 3.4±0.17 to 5.8±0.26 per cent and Ahmed and Kumar (2014) reported the crude fiber content as 1.75±0.36 per cent. Knife et al. (2015) evaluated three cultivar of chick pea and reported the result for crude fiber content between the ranges of 5.09±0.2 to 16.91±0.1.

Nour et al. (2015) reported the fiber content of sorghum as 2.34±0.024 and Iranna the fiber content ranged from 1.40 to 2.70 per cent. Nkama et al. (2015) reported the fiber content of sorghum as 3.19±0.16 per cent.

Kumar et al. (2013) reported crude fiber content as 3.91 per cent, Kaur et al. (2014) reported crude fiber 3.55±0.13 per cent. Singh et al. (2015) evaluated five cultivars of oats and reported crude fiber content ranged from 10.9-13.3 per cent.

Banusha and Vasanthruba (2013) reported 6.62±0.11 per cent crude fiber content and Emadou et al (2013) reported the crude fiber content 12.19 per cent. Thilagavathi et al. (2015) reported the fiber content 2.25±0.19 per cent

Polanisamy (2011) reported the crude fiber as 1.88±1.83 per cent Jain et al. (2012) evaluated two varieties of horse gram and reported the crude fiber content as 5.15±4.57 per cent. Kamboj and Nanda (2017) reported the crude fiber content of horse gram as 5.3 per cent.

v. Crude Protein

Arab et al. (2010) reported crude protein in chick pea as 24.63±1.33 per cent. Nobie et al. (2010) evaluated fourteen genotype of chick pea and obtained crude

protein ranged from 18.46±24.46 per cent, whereas, Saleem and Abou-Arab (2011) reported the crude protein content as 24.63±2.0 per cent.

Mohammed et al. (2011) analyzed protein content in sorghum as 12.25±0.00 per cent, whereas, Awadekareem et al. (2015) evaluated two cultivars of sorghum and reported protein content as 13.45±0.12 and 10.21±0.09 per cent and Nakma et al. (2015) calculated crude protein on the higher side i.e. 15.47±0.12 per cent.

Devi et al. (2011) analyzed finger millet for crude crude protein and reported the value as 7.3 per cent, whereas, Gunashree et al. (2014) calculated the values for same content as 6.8±0.01 per cent. whereas, Chauhan and Sarita (2018) reported crude protein finger millet as 6.3±0.20 per cent.

Ren et al. (2012) reported the crude protein content as 17.57±0.97 per cent, whereas, Kaur (2015) obtained 26.03 per cent crude protein content in rice bean.

Bilal et al. (2014) estimated 12.32±0.35 per cent crude protein. In the same year Kaur et al. obtained the values on the much higher side i.e.16.07±0.04 per cent. Singh et al. (2015) evaluated five cultivars of oats and obtained the values in the range of 12.9 - 14.4 per cent.

Amadou et al. (2013) reported the protein content in pearl millets as 14.8 per cent, whereas, Thilagavathi et al. (2015) obtained much less as 11.84±0.30 per cent. Adeoti et al. (2017) evaluated twenty two cultivars of pearls millet and reported protein content in wide range of 3.41±1.55 - 93.40±1.55 per cent.

Marimuthoo and Krishnamoorthi (2013) revealed the crude protein content in horse gram as 22.12±0.11 per cent. Jain et al. (2017) evaluated two varieties of horse gram and reported crude protein as 15.10 and 15.32 per cent. Simultaneously Kamboj and Nanda (2017) obtained the value for same constituent as 22.0 per cent.

vi. Carbohydrate

Tizazu et al. (2010) reported the carbohydrate content as 72.67 per cent in sorghum, Irana et al. (2012) also attempted to evaluate four varieties of sorghum and reported the carbohydrate content ranged from 70.65 to 7620 per cent. Whereas, Awadekareem et al. (2015) evaluated the two variety of sorghum and reported the carbohydrate content as 72.44±0.04 and 77.28±0.29 per cent.

Bhakre et al. (2012) reported the carbohydrate content in horse gram as 58.40 per cent. Jain et al. (2012) also attempted to evaluate two varieties of horse gram and reported the carbohydrate content as 74.88 and 76.06 per cent, after an year Marimuthu and Krishnamoorthi reported the same content in horse gram as 58.32±0.01 per cent.

Amadou et al. (2013) calculated the carbohydrate content in pearl millet as 59.8 per cent. whereas, Gull et al. (2015) reported much higher values for carbohydrate as 68.00±0.57 per cent. Thiagavathi et al. (2015) reported carbohydrate of pear millet as 65.5±2.36 per cent.

Arab et al. (2010) evaluated the carbohydrate content in chick pea flour as 64.76±1.0 per cent. Abu-Salem and Abou-Arab (2011) reported the carbohydrate content as 64.60±2.0 per cent in chick pea. Nobie et al. (2013) evaluated fourteen genotypes of chick pea and reported carbohydrate content ranged from 64.81±0.38 to 70.81±1.72 per cent,

Chappalevar et al. (2013) reported carbohydrate as 65.7 per cent in oat and Kaur et al. (2015) reported carbohydrate as 76.43±0.07 per cent. whereas, Singh et al. in 2015 reported the carbohydrate in the range of 55.7 to 59.7 per cent in five cultivars of oats.

Shibairi et al. (2014) evaluated six genotypes of finger millet and reported carbohydrate content ranged from 75.57 to 78.46 per cent. Gull et al. (2015) reprted the carbohydrate content in finger millet as 68.00±0.57 per cent Nazni and Bhuvneshwari (2015) reported the carbohydrate content in finger millet as 75±2.21 per cent, and Kaur (2015) reported available carbohydrate content of rice bean as 62.06 per cent.

2.1.d. Nutritional Parameter

i. **Dietary Fiber**

Hidalgo et al. (1997) reported the values for ADF, NDF, Cellulose hemicelluloses and lignin in chick pea as 6.59±0.37, 17.40±1.55, 5.86±0.34, 11.54 and 0.73±0.10 per cent respectively.

Sreeeama et al. (2007) also made an effort to analyzed dietary fiber content in horse gram and reported the values as 15.08 per cent. Marimuthu and Krishnamoorthi (2013) obtained the value as 12.14±0.12 per cent.

Mahmood et al. (2013) reported the values of ADF, NDF in fifteen varieties of sorghum as ranged from 24.4 to 40.8 and 46 to 59.5 per cent respectively.

Tosh et al. (2013) analyzed dietary fiber constituent content in chick pea as 26.2±2.7 per cent and Belino et al. (2015) reported the dietary fiber content as 13.70g.

Bilal et al. (2014) reported dietary fiber content of oat as 6.06±0.21 per cent.

Kaur et al. (2014) evaluated oats for ADF, NDF, Lignin Cellulose and hemicelluloses and reported the values as 3.98±0.20, 16.42±81, 1.65±0.05, 1.40±0.61, 4.91±0.10 per cent respectively.

Kaur and Thakur (2016) calculated the values for ADF, NDF, Lignin, Cellulose, and hemicelluloses in pearl millet as 54.3, 382.0, 4.0, 17.7, 327.7 g/kg respectively.

Thippeswamy et al. (2016) reported dietary fiber in finger millet as 13.44 per cent Devi et al. (2011) reported total dietary fiber as 19.1 per cent.

Rao et al. (2017) reported dietary fiber content of pearl millet as 11.49±0.62 per cent.

ii. Sugar

Nirmala et al. (2000) evaluated finger millet for sugars and reported the value for reducing sugars and non reducing sugar as 1.5 per cent and 0.3 per cent respectively.

Singhai and Shrivasthva (2006) evaluated five varieties of chick pea and reported reducing and non reducing sugars ranged from 24.0-32.0 and 16.6-24.4 per cent respectively.

Gunashree et al. (2014) calculated total sugar in finger millet as 74.7±0.036 per cent.

Garg and Sabharwal (2014) reported total sugar, reducing, non reducing sugars of two varieties of chic k pea as 9.76±0.39 and 9.20±0.70, 1.33±0.21 and 1.52±0.30, and 8.13±0.19 and 7.68±0.40 per cent respectively.

Mamta (2015) estimated total sugar, reducing sugar, non reducing sugars in two varieties of pearl millet as 2.41±0.09 and 2.50±0.04, 0.48±0.05 and 0.59±0.03 and 1.82±0.02 and 1.93±0.97 per cent respectively. Thilagavathi et al. (2015) reported total sugar (2.79±0.02), reducing sugar (0.73±0.02), non reducing sugar (1.96±0.01) per cent in pearl millet respectively.

Nutan (2015) reported total sugar, reducing sugar, non reducing sugar in oat as 1.68±0.09, 0.50±0.02 and 1.18±0.01 per cent respectively.

Thiagavathi et al. (2015) also evaluated the horse gram for sugars and reported total sugar, reducing sugar and non reducing sugar as 4.89±0.21, 0.82±0.02, 4.00±0.09 per cent respectively.

2.1.e. Minerals

Abou Arab et al. (2010) reported the mineral content of chick pea as K (102.50), Ca (42.91), Na (1.42), Mg (89.97), Cu (0.38), Fe (2.70) and Zn (2.19) mg/100g, Belino et a (2015) reported the mineral content of chick pea as Ca (129), Fe (12.0), and K (65) mg/100g.

Vanisha et al. (2011) evaluated pearl millet from four different sources and reported the minerals content ranged from Ca 25-42; P 26, Fe 3.0 - 11 Zn 22 - 31; Na 5-10 and Mg 106 to 137 mg/100g respectively. Ahmed et al. (2009) reported the mineral content in the same Na, K, Ca, Mg, Cu, Fe, Mn, and Zn as 2.08, 38.48, 16.08, 121.97, 3.87, 186.57, 20.98 and 72.90 mg/100g respectively.

Ahmed et al. (2014) also tested oats for its mineral composition as calcium, iron, magnesium, potassium and reported the values as 54.0, 5.0, 177.0, 429.0 mg/100g respectively. Later on Jakobsone et al. in 2015 also reported the minerals in oats namely Cd, Pb, Cr, Ni, Al, Cu, K, Na, Ca, Mn, Mg, Fe and Zn and reported the values as 0.0180, 0.043, 0.4900, 1.0888, 5.6460, 3.744, 3803.4, 83.9, 766.8, 38.8, 1365.5, 43.6 and 287.0 respectively.

Mohammed et al. (2011) evaluated sorghum for mineral constituents and reported the values for for Ca, P, Fe, Mg, Zn and Cu 3.75±0.39, 100.60±8.40, 2.24±0.40, 75.0±3.61, 0.75±0.07 and 0.61±0.09 mg/100g respectively. Pontieri et al. (2014) reported the mineral content of sorghum in seven hybrids as potassium ranged from 3434.46±33.56 to 6957±67.97 mg/kg; Na (489.69±5.38 to 840.64±9.25); Mg (1454092±7.71 to 2862±15.16 mg/kg); Ca (233.84±1.57 to 411.83±2.76 mg/kg) and P 2148.60±20.44 - 2963.40±28.55) mg/kg.

Thilagavathi et al. (2015) evaluated pearl millet and reported the mineral content such as Ca (39.63±1.06), Iron (9.60±0.017), Phosphorous (256.42±6.23), Potassium (287.51±12.70), Copper (1.47±0.06) and Zinc (2.49±0.07) mg/100 mg, respectively.

Thirukumar and Sindumathi (2014) reported the values for minerals in horse gram as Ca (231.00), Fe (14.20) and P (315.00) mg/100mg, respectively. after an year Thilgavathi et al. (2015) evaluated horse gram and reported the minerals composition as Ca 25.32±3.19; Iron (6.94±0.16); Phosphorous (298.72±8.82); Magnesium (165.34±2.16); Manganese (3.92±0.12); Sodium (16.65±0.69); Potassium (367.73±13.91); Copper (2.47±0.02) and Zinc (3.47±0.14) mg/100g.

Gunashree et al. (2014) reported the mineral content in finger millet as Ca (280.6), Mg (350), Cu (71), Mn 246), Fe (4.97), Zn (2.56), K (5.34) and Na (0.83) mg/100g, respectively. Chauhan and Sarita (2018) tried to evaluate composition in finger millet and obtained the values for Ca (342.4±1.36), Fe 3.7±0.06) and P (2801±123) mg/100gm.

2.1.f. Amino Acids

Arab and colleague (2010) evaluated the amino acid profile in chick pea and reported the values as Leucine (7.59), Isolucine (4.76), Lysine (6.00), Methionine (1.54), Phenyl alanine (5.57), Theronine (3.89), Valine (5.60), Cystine (1.36), Tyrosine (3.58), Alanine (4.88), Arginine (7.82), Aspartic (acid (11.18), Glumatic acid (18.05), Glycine (4.30), Histidine (2.96), Protein 4.68 and serine as 4.77 g/100g respectively.

Amadeu et al. (2013) reported amino acid content in pearl millet as Isoleucine (4.59) Lucine (13.60), Lysine (1.59), Methionine (3.06), Phenylalanine

(6.27),Threonine (3.68), Valine (5.81), Histidine (2.11), Alanine (9.30), Arginine (3.00), Aspartic acid (7.71), Cystine (0.45), Glutamic acid (22.00) Glycine (2.91) Serine (4.56), tyrosine (2.44) and Proline (5.54) g/100g.

An extensive study on amino acid profile was made by Sangwan and team in 2014 in oat and reported the values (156g) and reported amino acid values as tryptophan (0.365), Threonine (0.897), Isolucine (1.083), Lucine (2.003), lycine (1.094), Methionine (0.487), Cystine (0.636), Phenylalanine (1.396), Tyrosine (0.894), Vatine (1.462), Arginine (1.860), Histine (0.632), Alanine (1.374), Aspartic acid (2.259), Glumatic acid (5.791), Glycine (1.312), Proline (1.457) and Serine (1.170) grams.

Thapliyal and Singh in 2015 made exhaustive study to amino acid profile in finger millet and they obtained the values for different amino acids as 4.3 (isolucine), 10.8 (Lucine), 2.2 (lysine), 2.3 (histidine), 6.0 (alanine), 3.4 (arginine), 5.7 (Aspartic acid) 23.2 (glutamic acid), 3.3 (glysine), 5.3(serine), 3.6 (tyrosine) and 9.9 (prolein) g/100g.

Kamboj and Nanda (2017) reported the amino acid content in horse gram such as Arginine (530),Histiline (190), Lysine (520), Tryptophan (70), Phenylolanine (380), Methionine (70), Cystine (130), Thyronine (230), Lucine (540), Isolucine (370) and valine (390) mg/g respectively.

2.1.g Phytochemicals

Alajaji et al. (2006) recorded tannin and saponin content in chick pea as 4.85±0.05 and 0.91±1.0 mg/g respectively.

Florence and Urooj (2014) reported the tannin content in two cultivars of pearl millet as 0.23±0.01 and 0.21±0.02g/100g respectively. Thereafter, Thilagavathi et al. (2015) obtained the tannin content of pearl millet as 22.53±0.24 mgTAE/100g.

Folasade (2011) reported tannin and saponin in finger millet as 5.50±0.00 and 1.60±0.10 mg/100g respectively. Sundram et al. (2013) reported tannin and saponin of horse gram as 0.101±0.093 and 0.117±0.049 g/100g GAE respectively. Marimuthu and Karishnamoorthi (2015) reported tannin and saponin in horse gram as 0.104±0.03, 0.112±0.10 g/100g respectively. Subsequently in the same year Olosude

et al. reported the values for the same constituent in sorghum as 1.69 and 0.83 mg/100 respectively. whereas, Nour et al. (2015) reported much less value in sorghum as 0.15 mg/100g.

2.1.h. Starch and Resistant Starch

Alajaji et al. (2006) reported the starch content in chick pea as 36.01±0.60 g/100g. Stevenson et al. (2007), reported starch content of oat Kernel as 7.88 per cent.

Sreerama et al. (2012) reported the resistant starch content of horse gram as 2.2±0.2g/100g and Marimuthoo and Krishnamoorthi (2013) reported the resistant starch content of horse gram as 2.15±0.20 g/100g. Thilagavathi et al. (2015) reported the starch and amylose content of horse gram as 28.62±1.11 and 12.46±0.20 g/100g

Thilagavathi et al. (2015) reported the starch and amylose content of pearl millet as 56.82 ±1.18 and 22.18±0.39 g/100g. Alison et al. (2016) evaluated oat for starch and registrant starch and reported values as 69.2 and 3.7 per cent respectively. Adeoti et al. (2017) evaluated 22 varieties of oats and reported starch as vary from 50.51mg/g to 570.7 mg/g however, amylose content 39.78±2.08 to 491.0 mg/g. In the same year Rao et al. reported starch content of pearl millet as 55.21±2.57 g/100g.

2.1.i Amylose

Stevenson et al. (2007) reported the amylose content of oat kernel as 33.6 g/100g while studied the composition of oat.

Jukanti et al. (2012) in their work reported the amylose content of chick pea as 30-40 per cent.

Thilagavathi and associates (2015) in their work on the evaluation as of chemical constituents in horse gram reported the value for amylose as 12.46±0.20g/100g.

Thilagavathi et al. (2015) reported the amylose content of pearl millet as 22.18±0.39 g/100g. Adeoti et al. (2017) evaluated 22 varieties of oat and reported that starch content varied from 39.78±2.08 - 491.9 g.

2.2 Development of value added products using selected test crops

Survey of literature reveals that there is different type of information available regarding the formulation of development of bread, soup sticks, rusk and kurkure. Researchers used various types of compositions for the development of products and scanty information is available on the similar compositions.

2.3 Evaluation of prepared products

After a through scanning of literature, exactly no same type of compositions was obtained. There is scanty information available in literature on the effect of storage on nutritional value with the different compositions of products by similar crops and their blends

Zeppa et al. (2007) developed two types of bread sticks *viz.* stretched and rolled and reported the per cent moisture, ash, protein and carbohydrate as 6.63 & 8.62, 0.44 & 0.62, 12.17 & 11.02, 64.90 & 64.35 respectively.

Reddy et al. (2013) formulated and analysed six extruded products like kurkure made with corn flour, black gram,patio, taro, yam, sweet potao and beet root. They reported protein ranged from 10.46±0.16 – 6.09±0.18; moisture 2.14±0.23 – 3.29±0.18; fiber 0.68±0.06 – 1.41±0.18 and carbohydrate 68.22±0.48 – 75.64±0.44 per cent respectively.

Dhanimseti and colleagures (2016) also made an effort to prepare bread by using soyabean, ragi and flaxseeds in different composition i.e. 15, 20 and 25 per cent. They reported the hardness in the range of 1.581 – 3.057kg. Moisture content ranged from 33.48 – 36.04; fat 4.05 – 8.43; crude protein 9.37 – 13.93; ash 1.38 – 2.53; dietary fiber 1.05 – 3.22 and carbohydrate 35.85 – 50.67 per cent respectively.

According to Chaturvedi and Rawat (2018) prepared rusk by using unmalted and malted barnyard millet flour which contained moisture 9.78±0.14 & 10.51±0.15; protein 10.62±0.18 &11.12±0.19; fat 3.00±0.02 & 2.36±0.05; fiber 6.37±0.15 & 7.26±0.07; ash 2.05±0.04 & 2.42±0.09 and carbohydrate 67.37±0.41 & 66.35±0.26 per cent respectively. Iron and calcium were calculated as 5.42±0.56 & 9.09±0.07 and 313.49±0.05 & 319.23±0.14 mg/100g respectively.

Chandra et al. (2018) also prepared bread by blending wheat, soya, gram and barely flour, at different proportions. They reported moisture content ranged from 12.12 – 12.85; protein 1.08 – 1.32; fat 0.38 – 0 50; fiber 0.82 – 1.26 and carbohydrate 96.57 – 97.64 per cent respectively.

Sattar et al. (2018) reported the hardness of breadsticks prepared by using non germinated lentil, germinated lentil, non germinated green gram, germinated green gram, non germinated black gram and germinated black gram breadsticks as 66.86±10.5, 52.69±3.39, 18.67±0.96, 51.90±4.40, 15.99±0.71,41.96±10.1 and 33.88±2.52 respectively.

3. MATERIALS AND METHODS

The present investigation **"Characterization of selected cereals and pulses for the development of functional foods"** was conducted in the Department of Food Science, Nutrition and Technology, College of Home Science, CSK HPKV, Palampur. Materials and methods employed are described in the following heads and sub-heads:

3.1 Screening and identification of high fiber and low protein coarser grain/pulses

3.2 Optimization of baked and extruded snacks using identified sources

3.3 Physicochemical, functional and quality assessment of developed food matrix

3.4 Assessment of sensory and shelf stability of develop products

To ascertain the quality traits of the products, the raw material was tested physically as well as chemically. The standard techniques and methodologies were followed in the evaluation of quality parameters.

3.1.1 Procurement of raw material

The raw material was procured and purchased from the local market (Palampur) of district Kangra, Himachal Pradesh. The other ingredients for the formulations of value added products were purchased from the local market.

3.1.2 Preparation of samples

The procured samples were cleaned manually for removing adhering dirt, dust and foreign particles. The grains were ground into fine flour to a specific particle size i.e. with fifty two BSS sieve, stored in airtight food grade containers and stored at ambient temperature for further use. All the analysis was carried out in triplicates to reduce any error.

3.1.3 Physical evaluation

i. Colour and Shape

The colour and shape of the selected seeds of the test samples were observed from their physical and visual appearance.

ii. **Thousand kernel (seed) weight (Varnamkhasti et al., 2008)**

Thousand kernels (seed) weight was determined by weight of randomly selected 100 kernels by means of electronic balance (accuracy of 0.001 g) and multiplying their weight by 10.

iii. True density (Garnayak et al. 2008)

The true density was measured by toluene displacement method.

One thousand grains of test crops were weighed and put in graduated cylinder containing known amount of toluene. Rise in toluene level was noted and true density was reported by using the formulae

$$True\ desnsity\ (g/ml) = \frac{W\ (g)}{V\ (ml)}$$

Where 'W' is weight of one thousand grains and 'V' is rise in toluene level after the addition of the grains.

iv. Bulk density (Garnayak et al. 2008)

The grains of test crops were filled in measuring cylinders up to certain level from the constant height followed by weighing. The bulk density was determined by using the formula

$$Bulk\ desity\ (g/ml) = \frac{Weight\ (g)}{Volume\ (ml)}$$

v. Porosity (Jain and Bal, 1997)

Porosity was analyzed by using the relationship of bulk density and true density as follows.

$$Porosity = 1 - \frac{(true\ density - bulk\ density)}{Bulk\ density} \times 100$$

3.1.4 Functional properties evaluation

i. Water absorption index (WAI) and Water solubility index (WSI) (Anderson, 1982)

Accurately weighed 2.0 g sample was taken in centrifuge tube, which was previously dried and weighed followed by 20ml of distilled water and kept in water bath for 10 minutes at 85^0C. Sample was cooled and centrifuged at 3500 rpm for 15 minutes. Supernatant was decanted in preweighed petriplate and sediment was weighed.

For water solubility index after centrifuging at 3500 rpm for 15 minutes, the supernatant decanted in preweighed petriplate. Then dried for 1-2 hours at 100^0C and weighed. The WAI and WSI were calculated by the following formulas.

$$WAI = \frac{Weight\ of\ sediment\ (g)}{Weight\ of\ solids\ (g)}$$

$$WSI = \frac{Weight\ of\ dissolve\ solids\ in\ supernatant\ (dried)}{Weight\ of\ dry\ solids} \times 100$$

ii. Water and Oil absorption capacity (Sosulski et al., 1976)

The sample (1.0 g) was mixed with 10 ml water or refined soybean oil, kept at ambient temperature for 30 minutes and centrifuged for 10 minutes at 2000 rpm. Water or oil absorption capacity was expressed as per cent oil bound per gram of the sample.

iii. Foaming capacity and Foaming stability

The Foaming capacity (FC) and the Foam stability (FS) of the flour samples were determined by slightly modifying the procedure suggested by Kaur and Singh (2005). The dispersion of flour samples in 50 ml of distilled water at the rate of 3% w/v was homogenized vigorously for 3-5 minutes using a high-speed scattering machine at 10,000 rpm The blend is immediately transferred to a graduated cylinder and the homogenizer cup was rinsed with 10 mL distilled water, which was then added to the graduated cylinder. The volume was recorded before and after whipping and measured as the percent of volume increase due to whipping. The foaming

capacity was expressed as the percentage of volume increase. For the determination of foaming stability, a change in the foam volume in the graduated cylinder was recorded after 1 hour of storage. The FC and FS were calculated by the following formulas.

$$FC\ (\%) = \frac{V2 - V1}{V2} \times 100$$

$$FS\ (\%) = \frac{V3}{V2 - V1} \times 100$$

3.1.5 Chemical and nutritional evaluation

3.1.5. 1Chemical evaluation

i Moisture Content (AOAC, 2005)

Accurately weighed 5.0 g sample was taken in pertidish, which was previously dried and weighed. The moisture cup along with sample was placed in the oven maintained at 105±1°C for 3-4 hours, by repeating the process of drying, cooling and weighing at 30 min intervals, until the difference between consecutive weights was less than 1mg. Then it was transferred to a desiccator and cooled. Then it was weighed. The percent moisture content (w.b) was calculated as :

$$Moistur\ content\ (\%\ w.b) = \frac{(w_2 - w)}{w_1 - w} \times 100$$

Where; W = Weight of empty petridish, (g)

W1 = Weight of petridish with sample before drying, (g)

W2 = Weight of petridish with sample after drying to constant weight, (g)

ii. **Ash content (AOAC, 2005)**

Accurately weighed 2g sample was put in to a crucible, previously dried and weighed. The crucible with sample was heated gently on a flame for complete charring and then it was heated in a muffle furnace at 550 ± 10°C for 4 – 5 h, until ash was formed, cooled in a desiccator and weighed. The percent ash content can be calculated as

$$Total\ ash\ (\%) = \frac{(w_2 \_ w)}{(w_1 - w)} \times 100$$

Where; W = Weight of empty dish, g

W1 = Weight of dish with sample, g

W2 = Weight of dish with ash, g

iii Protein content

Protein content of the test flour was determined by Kjeldhal method (AOAC, 2005). About 5.0 g of digestion mixture (Potassium sulphate, Copper sulphate and selenium dioxide in the proportions of 25:5:1), 0.5-1g of sample and 10ml of sulphuric acid (H2SO4) in a digestion tube were kept at about 340°C for approximately 1h. The digest was cooled and 30ml of distilled water was added to it. The digest was then steam distilled after addition of 40% NaOH. After distillation the liberated ammonia was trapped in the 20ml of 4% boric acid containing 4-5 drops of mixed indicator, {1% Bromocresol green + 0.1% Methyl Red (1:2)}. The colour of the boric acid changes from purple to bluish green with entrapment of liberated ammonia. Then boric acid was titrated with 0.5N HCL and the colour of the boric acid again changes to light purple.

Calculation:

The protein content was determined by using the following formula:

$$Nitrogen\ (\%) = \frac{(sample\ titre - sample\ blank) \times 14 \times N \times 100}{W \times 1000}$$

Where; N = normality of standard HCL solution

W = weight of sample

Amount of protein was obtained by multiplying the nitrogen (%) with the appropriate conversion factor (i.e. 5.54 for cereal grains & 5.51 for pulses).

iv Fat content

Weighed samples of 5.00 g each in triplicate were extracted with petroleum ether in Soxhlet extraction apparatus for 18 hours. The ether extract was filtered through a sintered funnel in a pre-weighed beaker and was washed with small volume of petroleum ether 2-3 times. The petroleum ether was completely evaporated and the beakers were weighed. The amount of fat present in the sample was calculated as:

$$Fat\ content\ (\%) = \frac{(w_2 - w_1)}{w} \times 100$$

Where; W1-Weight of empty beaker (g)

W2- Weight of beaker with oil (g)

W- Weight of sample (g)

v Crude fiber content

2.0 g sample (W) was taken. Digestion was done with 200ml H_2SO_4 (0.255N) for 30 min. During digestion glass beads were added. Residue was washed with hot distilled water. Then digestion was done with 200 ml NaOH (0.313N) for 30 minutes and washed again with hot distilled water. Then residue was washed with 15 ml ethanol. This residue was dried in hot air oven (100^oC) until constant weight (W1) was obtained. Then it was kept in muffle furnace at 550oC for 5 h till all the carbonaceous matter was burnt. Weight (W2) was taken after it get cooled (AOAC, 2005).

$$Crude\ fiber\ content(\%) = \frac{(w_1 - w_2)}{w} \times 100$$

vi. Total carbohydrates (NIN, 1983)

The content of per cent available carbohydrates was determined by different method i.e. by subtracting from 100, the sum of percent values of moisture, crude protein, crude fat, crude ash and crude fibre. The values were expressed as total carbohydrates (%) in the samples.

Total carbohydrates (%) = 100- (moisture% + protein% + fat% + fibre% + ash %)

3.1.5.2 Nutritional Parameters

The following nutritional parameters were analyzed by using standard methods:

I. Dietary fiber constituents (Soest and Wine, 1967)

II. **Neutral Detergent Fibre (NDF)**

Weighed 500 mg air dried sample in triplicate and transferred into a beaker of the refluxing apparatus. Added to this 100 ml of neutral detergent solution and heated to boiling. As it started boiling, heat was reduced to avoid foaming and allowed to

reflux for 60 minutes. Then filtered it through weighed Gooch crucible with minimum of hot water. Liquid was filtered and repeated the washing procedure. Then washed with acetone in the same manner. Dried the crucible in hot air oven at 100^{o}C for 8 hours and weighed after cooling. The NDF content was then calculated as:

$$Percent\ NDF = \frac{(Weight\ of\ Crucible + Fiber\ content) - Weight\ of\ crucible}{Weight\ of\ sample\ (g)} \times 100$$

a. Acid Detergent Fibre (ADF)

Weighed 500 mg of air dried sample was weighed and transferred to the beaker of the refluxing apparatus. 100 ml of acid detergent solution was added to it and the mixture was heated to boiled and refluxed for 60 minutes. The mixture was then filtered through a weighed Gooche crucible on filtered manifold. The sample was rinsed into the crucible with minimum to hot water. Liquid the filtered and washing was repeated. Then the sample was dried at 100^{o}C for 8 hours in hot air oven and weighed. The ADF content was then calculated as:

$$Per\ cent\ ADF = \frac{(Weight\ of\ crucible + Fiber\ content) - Weight\ of\ crucible}{Weight\ of\ Sample} \times 100$$

b. Lignin (Van Soet and Robertson 1985)

ADF was prepared as described in acid detergent fiber procedure. The crucible containing ADF was finned with 72 per cent H_2SO_4 and stirred with glass rod to smooth paste and to break lumps. Crucible was stirred at hourly interval as acid drains away. The crucible was kept at about 25^{0}C. After 3 hour filter off as much as acid as possible. The content was washed with hot water to free from acid. Rinsed and glass rod removed. Crucible was dried at 100^{0}C for 8 hours and weighed. Crucible was kept in the muffle furnace at 500^{0}C – 550^{0}C for 3 hours cool and weighed. The lignin content was then calculated as:

$$Lignin\ (\%) = \frac{(weight\ of\ crucible + lignin) - (Weight\ of\ crucible + ash)}{Weight\ of\ sample} \times 100$$

c. Hemicellulose (Van Soet and Robertson 1985)

Hemicellulose was calculated using following formula:

$$Hemicellulose = NDF - ADF$$

d. Cellulose (Van Soet and Robertson 1985)

Cellulose was calculated using following formula:

$$Cellulose = ADF - Lignin$$

i. Sugars (AOAC, 2010)

Extract preparation

Placed 5.675g finely ground powder of the test samples in 100ml Erlenmeyer flask. The flasks were tipped so that all the flour was at one side, then the flour was wetted with 5ml ethanol and 50ml acetate buffer solution was added to it. The flask was then shaked immediately and added 2ml sodium tungstate solution and again mixed thoroughly. The contents were filtered through the Whatman filter paper no.4 discarding first 8- 10 drops.

a. Reducing Sugars

Pipetted 5ml extract as described in extract preparation to test tubes. Added exactly 10 ml of potassium ferricyanide solution to test tubes, mixed and immersed the test tubes in the vigorously boiling water bath for 20 minutes. Then the test tubes were cold in running water and extract was poured at once into 100 ml Erlenmeyer flask. The tubes were rinsed with 25 ml acetate buffer salt solution, added washing to Erlenmeyer flask and mixed thoroughly. Then 1ml starch potassium iodide solution was added. Titrated with 0.1 N sodium thiosulphate solution until blue colour completely disappeared. Subtracted ml of sodium thiosulphate used in titration from 10.0. In case of blank in potassium ferricyanide and sodium thiosulphate titration, corrected by substracting from sodium thiosulphate equivalent in potassium ferricyanide solution. The difference represented definite amount of reducing sugar mg/10g flour, calculated as maltose Appendix – 1.

b. Non reducing sugars

Piptted 5ml flour extract into test tubes and immersed in vigorously boiling water bath. After boling for 15 min. they were cold under running tab water and exactly 10ml potassium ferricyanide solution was added and processed as in reducing sugars. Potassium ferricyanide reduced by maltose in flour is equal to non reducing sugars called as sucrose determined from Appendix – 1.

c. Total Sugar

Total sugars in the samples were calculated as the sum of reducing sugars and non reducing sugars.

ii. Minerals

Digestion

One gram of finely ground sample (seeds and leaves) was taken in 150 ml conical flask. To this 25 ml of diacid mixture (HNO_3: $HClO_4$ in 5:1 v/v) was added and kept overnight. Digestion was done on the next day by heating till clear white precipitates settle down at the bottom. The crystals were dissolved by diluting in double distilled water. The contents were filtered through Whatman filter paper No. 42. The filtrate was made to 25 ml volume with double distilled water and used for determination of potassium, copper, zinc, manganese, and iron by using atomic absorption spectrophotometer, Model 3100, Perkin Elmer. Calcium and Sodium was determined with the help of flame photometer, Mediflame, 127.

iii. Amino acids

Amino acid profiling was done by using High performance liquid chromatography.

Samples were grinded and passed through a sieve of 52 BSS pore size to get uniform sized particles of flour. Screw capped test tubes were taken for hydrolysis process. They were dipped in 0.1 M HCl for the whole night to avoid any sort of contamination. Each sample was accurately weighed at about 0.2 g with the help of analytical balance and was put into test tubes containing 12 ml of 6 M HCl. Tubes were evacuated by nitrogen flushing and were capped immediately. Tubes containing samples and HCl were put in an oven for about 24 hours for complete hydrolysis of test samples. Samples were taken out from the oven after specified time, cooled to room temperature, and dried to remove HCl. Samples were reconstituted again in 3 ml of 0.02 M HCl. Each one was filtered carefully through 0.22 µm filter paper to remove small sized contaminants prior to centrifugation. The supernatant was derivatized and then filtered using a 0.45-µm PTFE membrane before injection in HPLC. HPLC instrument was equipped with auto injector, column compartment, fluorescent detector (G1315B), vacuum degasser, and quaternary pump. Separation was performed on Eclipse XDB C18 Column (ID 2.1 × 150 mm, 5 µ particle size) at 40°C. Peak monitoring was achieved on a fluorescent detector with excitation wavelength being λ_{ex} =340nm and emission being λ_{em} =450 nm.

3.1.6 Phyto chemical evaluation

i. Saponin (Obadoni and Ochuko 2001).

Twenty gram of ground samples were dispersed in 200 ml of 20 per cent ethanol. The suspension was heated over a hot water bath (55^{o}C) for 4 hours with continuous stirring. The mixture was filtered and the residue re-extracted with another 200 ml of 20 per cent ethanol. The combined extract was reduced to 40 ml over a water bath at about 90^{o}C. The concentrate was transferred in to a 250 ml separator funnel and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated and 60 ml of *n*-butanol was added. The combined *n*-butanol extracts were washed twice with 10 ml of 5 per cent aqueous sodium chloride. The remaining solution was heated in a water bath. After evaporation, the samples were dried in the oven to a constant weight. The saponin content was calculated in per cent.

ii. Tannin

Using the method of Makkar et al. (1993) for determination of non-tannin phenolics, 100 mg sample was *weighted in* test tubes before being added with 1.0 mL distilled water and 1.0 mL of the extracted sample. The tubes were vortexed before kept at 4°C for 15 min. Then, the tubes were vortexed again before centrifuged at 3000 rpm for 10 min. The supernatant was collected and measured for absorbance at 725 nm using spectrophotometer (Shimadzu, Australia). The tannin content was calculated as follows: $Tannin = Total\ Phenlic - non\ tannin$

Total phenolic and tannin content were expressed as gallic acid equivalents through the calibration curve of gallic acid with the concentration range of 0-100 mg/ml**.**

3.1.7. Determination of Total starch

Total starch (TS) was determined by the AOCC Method 76.13 using the Total Starch Assay Procedure Kit (Megazyme Int, Ireland). A 100 mg of dried ground sample was dispersed with 0.2 mL of aqueous ethanol (80%v/v). Immediately 3 ml of thermostable α-amylase in a MOPS buffer was added and the tube was incubated in a boiling water bath for 6 min with continuous stirring alternately after 2 to 4 minutes. The tube was placed in a water bath at 50°C, and 4 mL of sodium acetate buffer (200

mM, pH 4.5) was added followed by amyloglucosidase (0.1 mL, 20 U).The tube was stirred on a vortex mixer and Incubated at 50°C for 30 min. Then, the volume was adjusted to 100 mL with distilled water. An aliquot of this solution was centrifuged at 3,000 rpm for 10 min. Duplicate aliquots (0.1 mL) were transferred to test tubes and 3 mL of the glucose oxidase reagent was added. The incubation with the reagent was done at 50°C for 20 min, and the absorbance was measured at a wavelength of 510 nm against the reagent blank. Glucose concentration was converted into starch by multiplying by 0.9.

3.1.8 Determination of Resistant starch

Resistant starch (RS) was determined enzymatically by the method of Goni et al. (1996). 100 mg of ground sample was incubated with a solution of 20 mg of pepsin from porcine gastric mucosa (P-7000) in a KCl- HCl buffer for 60 min at 40°C. After cooling the sample at room temperature, 9 mL of 0.1 M Tris-maleate buffer (pH 6.9) was added followed by 1 ml of a solution of 40 mg of α –amylase from porcine pancreas (A-3176.). The sample was incubated at 37°C for 16 h with constant shaking. The hydrolyzate was centrifuged and the supernatant discarded. The residue was moistened and 3 mL of KOH was added to solubilize the residual starch, shaking for 30 min at room temperature. After adjusting the pH to 4.75 (using 0.4 M sodium acetate buffer and 2 M HCl), 80 µl of amyloglucosidase from Aspergillus niger (A-1602, Sigma-Aldrich Inc.) was added, mixed well and left for 45 min in a water bath at 60°C with constant shaking. The solution was centrifuged and the supernatant collected in a 25 mL volumetric flask. After adjusting the volume with distilled water, duplicate aliquots (0.1 mL) of this solution were transferred into test tubes and the reagent from the glucose determination kit (Megazyme Int, Ireland) was added and the absorbance was read as described in the total starch analysis. The resistant starch was calculated as mg of glucose x 0.9.

3.1.9. Amylose content.

The amylose content was determined by following the colorimetric method of Morrison and Laignelet (1988). A 70 mg sample of starch was placed in a test tube followed by addition of 10 ml of urea (6M)-DMSO solution in the ratio of (1:9) ml with continuous stirring. After heating for 10 min in boiling water were then placed in

an oven at 100^{o}C for 1 hour followed by cooling at room temperature. A 0.5 ml of this solution was taken into a volumetric flask containing 25 ml distilled water and 1 ml of I_2 and KI (100 mg I_2 and 1000 mg KI in 50 ml distilled water). The volume was made volume up to 50 ml with distilled water and mixed completely. Absorbance of the samples was measured at 635nm in a spectrometer against a blank (prepared by allowing chemicals and distilled water to stabilize for 15 minutes).

$$\%(Amylose) = \left(\frac{Absorbance \ \times 100}{2 \ \times g \ solution \ \times mg \ starch}\right) \times 100 \times 28.414$$

3.1.10. Hydrolysis index and estimated glycemic index

From the digestion curves obtained during starch hydrolysis, the area under the hydrolysis curve (AUC) was calculated for each sample using the equation:

$AUC = C_{\infty}(t_f - t_o) - \left(\frac{C_{\infty}}{K}\right)\left[1 - e^{-k(t_f - t_o)}\right]$, Where tf is the final time (180 min) and to is the initial time (0 min). The hydrolysis index (HI) was obtained by dividing the area under the hydrolysis curve of each sample by the corresponding area of a reference sample (fresh white bread, 18 GI=100) obtained from Goni et al. (1997). Finally, the estimated glycemic index (EGI) was predicted with the formula: EGI = 39.71 + (0.549 x HI).

3.1.11. *In-vitro* Antioxidant Activity

i. Determination of total phenolic content (TPC)

The TPC of test samples extract was determined with the Folin-Ciocalteu method as described by Taga et al. (1984). To 1 ml of the prepared extract, 9 ml of distilled water and 1 ml of the Folin–Ciocalteu reagent was added. Thereafter, 10 ml of 7% (w/v) Na_2CO_3 solution was added followed by 25 ml of distilled water with continuous stirring. The mixture was given a rest period of 90 min and the absorbance was measured against the reagent blank at 750 nm using spectrophotometer. Total phenolic content was expressed as Gallic acid equivalent (GAE)/g wt. TPC was calculated from the mathematical relationship between gallic acid at different concentrations (mg) and their corresponding absorbance given as: $y = 0.041x - 0.127$. (r^2=0.997)

Where; y is absorbance and x; concentration.

Results were expressed as mg Gallic acid equivalents in 1 g of dried sample (mg GAE/g).

ii. Determination of total flavonoid contents (TFC)

Total flavonoid contents (TFC) were determined using colorimetric method of Abu Bakar et al. (2009). To 0.5 ml of the test sampl extract 2.25 ml of distilled water was added in a test tube followed by addition of 0.15 ml of $NaNO_2$ solution (5% w/v). After 6 min, 0.3 ml of a 10% (w/v, $AlCl_3.6H_2O$) solution was added and given a rest period of 5 min, before 1.0 ml of 1 M NaOH was added and then mixed by using vortex mixer. The absorbance was measured immediately at 510 nm by using spectrophotometer. Mathematical relationship was established between Rutin at different concentration and their corresponding absorbance, which is given as follows:

$$y = 0.003x + 0.317 \ (r^2=0.997)$$

Results were expressed as mg rutin equivalents in 1 g of dried sample (mg RE/g).

3.1.12. In-vitro antioxidant capacity estimation

i. DPPH radical scavenging activity

Free radical scavenging activities of test flour extracts was determined with the aid of DPPH radical as described by Sasidharan et al. (2011). To 0.1 ml of the extract solutions, 3.9 ml of DPPH solution prepared by dissolving 2.3 mg of DPPH radical in 100 ml methanol was added and mixed thoroughly. The solution was given a rest period of 30 min in dark followed by measurement of the absorbance at 515 nm against reagent blank (control). The DPPH radical scavenging activity was calculated by the following equation:

DPPH radical scavenging %= $[1 \ / \ ((A515nm, sample - A515nm, control))] \times 100.$

ii. Determination of Ferric Reducing Antioxidant Activity (FRAP)

FRAP assay is based on ability of antioxidant to reduce Fe^{3+} to Fe^{2+} in the presence of 2,4,6-tri(2-pyridyl)-S-triazine(TPTZ) forming an intense blue Fe^{2+} -TPTZ complex with an absorption maximum at 593 nm. FRAP solution was prepared by mixing 2.5 mL of a 10 mM 2,4,6-TPTZ (2,4,6-tri(2-pyridyl)-1,3,5-triazine) solution in

40 mM hydrochloric acid with 2.5 ml of 20mM ferric chloride and 25mL of 0.3Macetate buffer (pH 3.6).

0.2 ml of the extract was mixed with 3.8 ml of FRAP reagent and the reaction mixture is incubated at 37^{o}C for 30 minutes. The absorbance was determined at 593 nm against $FeSO_4$ is used for calibration. The antioxidant capacity is based on the ability to reduce ferric ions of sample is calculated from the linear calibration curve and expressed as mM $FeSO_4$ equivalent per gm of the sample.

Development o the value added products using selected test crops

Response surface methodology (RSM) was used to design the experiment. Box Behkhen design was used with the help of software design expert 9.

Experimental Design

Response surface methodology (RSM) was used to design the experiment. Box Behkhen design was done for five independent variables of cereals . The high and low levels of five independent variables were chosen as discussed in pertinent tables. Each variable was tested by performing the preliminary trials and literature. The Box Behken design for the five independent variables at five levels each was performed for proximate composition. Product responses including moisture (%), fat (%), ash (%), protein (%) and fiber (%) were studied. RSM was used to optimize the level of cereals for formation of products (Bread, Soup sticks, Rusk and Kurkure), the optimized products were then assessed for storage studies of 120 days except bread. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

The different independent variables were chosen for different products. Independent variables for bread are wheat, oat, finger millet, pearl millet and sorghum, for soup sticks wheat, chick pea, rice bean, and horse gram, for rusk wheat,

oat, finger millet, pearl millet and sorghum and for kurkure wheat, oat, finger millet, pearl millet, sorghum chick pea, rice bean, and horse gram respectively. The high and low levels of responses were selected.

TABLE 3.1 : Experimental ranges and levels of independent variables using RSM in terms of actual and coded factors of bread.

Independent Variables		Responses		Level in coded form (Independent Variables)		Level in un coded form (Independent Variables)	
Variable	Symbol	Response	Units	Min.	Maxi.	Min.	Maxi.
Wheat	A	Moisture	%	-1	1	10	25
Oat	B	Ash	%	-1	1	25	35
Finger millet	C	Fat	%	-1	1	18	27
Pearl millet	D	Protein	%	-1	1	5	13
Sorghum	E	Fiber	%	-1	1	13	30

Table 3.2 Experimental ranges and levels of independent variables using RSM in terms of actual and coded factors of soup sticks.

Independent Variables		Responses		Level in coded form (Independent Variables)		Level in un coded form (Independent Variables)	
	Symbol		Units	Min.	Maxi.	Min.	Maxi.
Wheat	A	Moisture	%	-1	1	10	25
Chick pea	B	Ash	%	-1	1	15	42
Rice bean	C	Fat	%	-1	1	13	30
Horse gram	E	Fiber	%	-1	1	17	35

Table 3.3 Experimental ranges and levels of independent variables using RSM in terms of actual and coded factors of rusk.

Independent Variables		Responses		Level in coded form (Independent Variables)		Level in un coded form (Independent Variables)	
	Symbol		Units	Min.	Maxi.	Min.	Maxi.
Wheat	A	Moisture	%	-1	1	10	25
Oat	B	Ash	%	-1	1	18	36
Finger millet	C	Fat	%	-1	1	16	33
Pearl millet	D	Protein	%	-1	1	7	15
Sorghum	E	Fiber	%	-1	1	14	30

Table 3.4 Experimental ranges and levels of independent variables using RSM in terms of actual and coded factors of kurkure.

Independent Variables		Responses		Level in coded form (Independent Variables)		Level in un coded form (Independent Variables)	
	Symbol		Units	Min.	Maxi.	Min.	Maxi.
Wheat	A	Moisture	%	-1	1	9	15
Oat	B	Ash	%	-1	1	9	21
Finger millet	C	Fat	%	-1	1	7	17
Pearl millet	D	Protein	%	-1	1	4	8
Sorghum	E	Fiber	%	-1	1	7	16
Chick pea	F			-1	1	8	18
Rice bean	G			-1	1	3	11
Horse gram	H			-1	1	5	12

Method for Bread preparation:

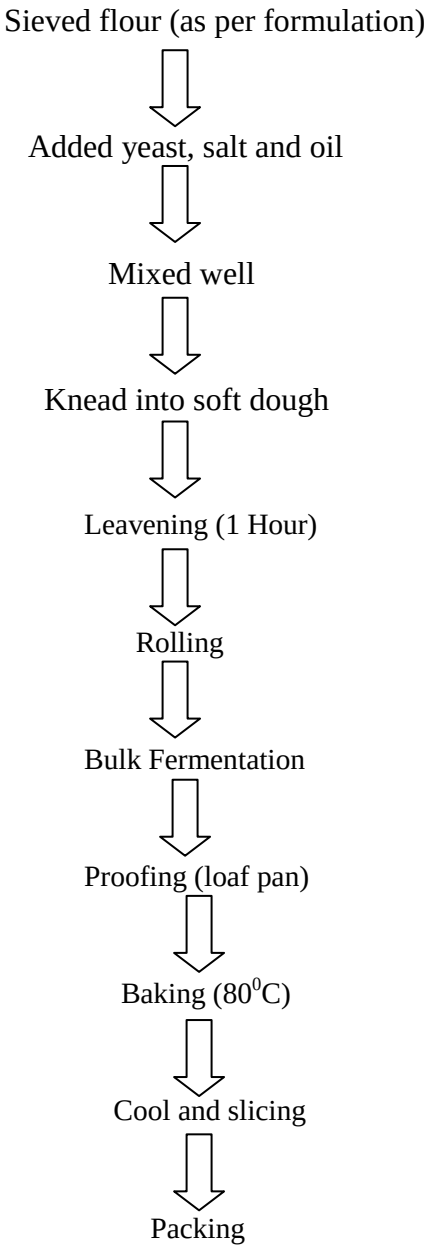


Figure 3.1: Flow chart for the preparation of Bread

Method for Soup Sticks preparation:

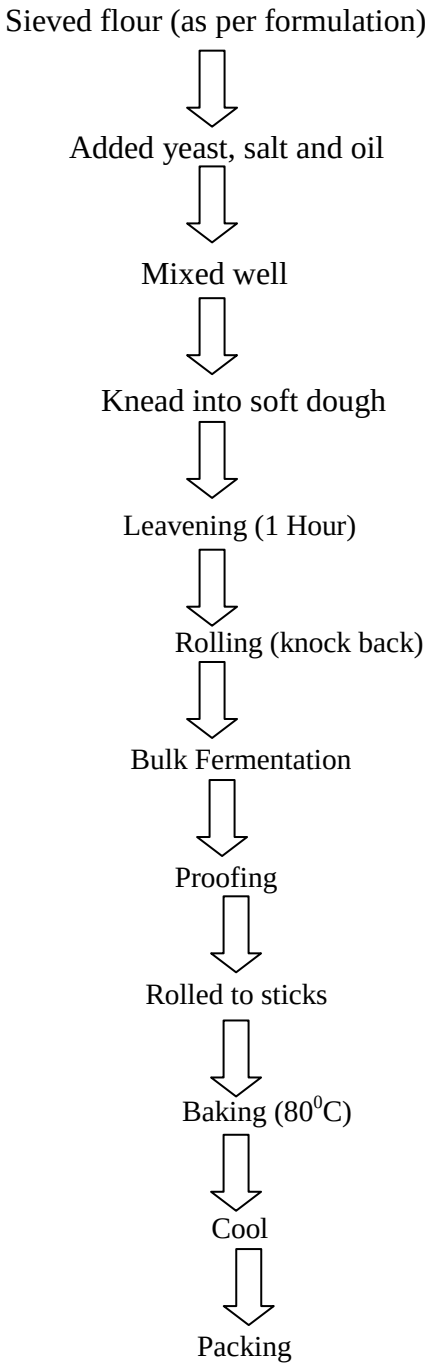


Figure 3.2 : Flow chart for the preparation of Soup Sticks

Method for Rusk preparation:

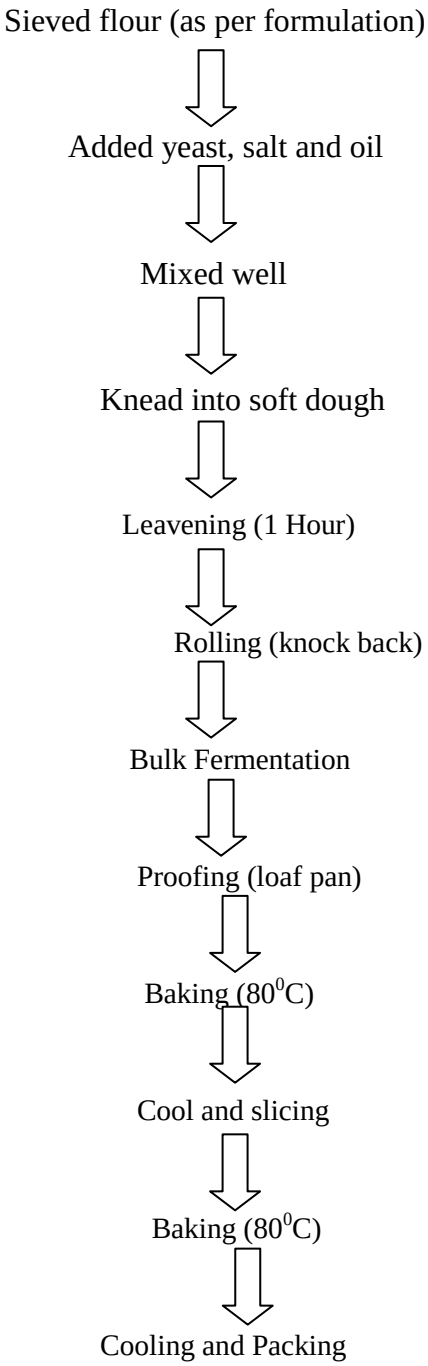


Figure 3.3 : Flow chart for the preparation of Rusk

Method for kurkure preparation

A laboratory scale co-rotating twinscrew extruder with intermeshing screws (Model BC21;Clextral, Firminy Cedex, France) was used for the preparation of kurkure. The barrel diameter and L/D ratio were 25mm and 16:1 respectively. Material was fed into the extruder inlet port by a screw feeder, motor (DS and M, Modena, Italy).The screw installed in the barrel performs the function of mixing and grinding. The feeder speed and screw speed were maintained at 60 rpm and 400 rpm respectively. Temperature in the four barrel section was set at 160ºC. The extruded samples were cooled at room temperature and sealed in a food grade bag packages and then airtight container and stored at ambient temperature for further analysis. Detailed recipies of the products are given in appendix III, IV, V respectively.

3.3 Texture analysis for prepared products:

The hardness of samples was measured using Texture Analyzer, model TA-XT2i (Stable Micro-Systems, Surrey, England) with a compression plate p75.

3.3.1. Organoleptic evaluation

The organoleptic evaluation was done as per method suggested by Gould (1978). The sensory attributes like colour, flavour, taste, texture and over all acceptability of the products were evaluated. A minimum of 10 judges were selected at random. The judges were required to record their preferences and acceptability of products on the evaluation sheets (Appendix II).

3.4. Storage Study

The prepared food products samples were kept for storage at ambient temperature to see the self stability. They were analyzed at fresh stage and after storage interval of 30, 60 90 and 120 days.

Analysis of data

The experiments were carried out in triplicate and the data so obtained is the mean values and standard deviations were obtained. The data obtained from antioxidant activities and product development and storage were subjected to Analysis of Variance.

4. RESULTS AND DISCUSSION

The present studies entitled "Characterization of selected cereals and pulses for the development of functional foods" was conducted in the Department of Food Science, Nutrition and Technology, College of Home Science, CSK HPKV, Palampur during 2014 - 2018

Results are discussed under the following heads and sub heads:

4.1 Screening and identification of high fiber and low protein coarser grain/pulses

4.2 Optimization of baked and extruded snacks using identified sources

4.3 Physio-chemical, functional and quality assessment of developed food matrix

4.4 Assessment of sensory and shelf stability of developed products

4.1 Screening and identification of high fiber and low protein coarser grain/pulses

The selected crops of cereals and pulses *viz.* oat (*Avena sativa*), finger millet (*Eleusine coracana L.)*, pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolour*), horse gram *(Macrotyloma uniflorum),* chick pea (*Cicer arietinum)* and rice bean (*Vigna umbellata*) were used for screening and identification of high fiber and low protein as coarser grain/pulses based on the following parameters:

4.1.1 Physical evaluation

4.1.2 Functional properties evaluation

4.1.3 Chemical and nutritional evaluation

4.1.4 Phyto-chemical evaluation

4.1.5 Antioxidant activities

4.1.1 Physical evaluation

Physical parameters of selected cereal crops

Cereals are staple foods, and are important sources of nutrients in both developed and developing countries. As cereals and cereal products are an important

source of energy, carbohydrate, protein and fibre, but they also contain a wide range of micronutrients. The selected cereals *viz.* Oat (*Avena sativa*), Finger millet (*Eleusine coracana L.)*, Pearl millet (*Pennisetum glaucum*) and Sorghum (*Sorghum bicolour*), were evaluated physically in terms of colour, shape, 1000 kernel weight, density, bulk density and porosity and results are presented in Table 4.1.

i. Oat (*Avena sativa)*

The Oat, locally called *Jaei*, belongs to the family *Poaceae* and species of *A. sativa* grown for its seed, Oat is most suitable for human consumption, as well as livestock feed.

Colour is an important quality attribute which increases the consumer acceptability for particular variety.The colour of oat grains are found to be creamish in colour with elongated spindle shape. As is evident from the Table 4.1 one 1000 kernel weight of the test sample came out to be 26.95 g whereas ,density and bulk density established as 1.0 g/ml and 0.58 g/ml respectively. The porosity value was calculated as 43.27 g/100 g. Singh et al. (2015) evaluated the five varieties of oat for the physical parameters and reported results of thousand kernel weight and bulk density between the range of 20.5 to 27.8 g and 0.73 to 0.77g/ml respectively. These variations might be due to agro-climatic conditions coupled with varietal variations. The bulk density is the measure of heaviness of the flour and is generally affected by the particle size and the density of the flour. It is very important in determining the packaging requirement, material handling and application in wet processing in the food industry .Porosity and density are the basic attributes used to solve the problems of agricultural products during drying and storage periods and to maintain the quality characteristics until consumption. The lesser thousand kernel weight indicates the presence of damaged, immature and shriveled grains, which in turn results in poor milling yield

ii. Pearl millet (*Pennisetum glaucum*)

It is belongs to the family *Poaceae*, is the most widely grown type of millet. It has a special quality to withstand harsh weather conditions like drought and flood which make it a major source of food to the residents of the arid and sub-arid regions. The colour of the pearl millet was gray and shape of the pearl millet was found to be oval. The Table 4.1 shows the mean 1000 kernel weight, density and bulk density as

9.05, 1.45g and 0.72g/ml respectively. The value for porosity calculated as 20.12g/100g. Physical parameters of two varieties of Pearl millet as observed by the Ojediran et al. (2010) who repoterd the results for thousand kernel weight, density, bulk density and porosity as 7.30 – 9.47g, 0.96 – 0.99g/ml, 0.81 – 0.82 g/ml and 15.17 to 17.28 g/100g respectively. The results for 1000 kernel weight and bulk density are in line with the present results. However, values for density and porosity are on the higher sides which might be due to because of high starch, low content of protein and fat in finger millet.

iii. Sorghum, (*Sorghum bicolour*)

Sorghum, also called Great millet, Indian millet belongs to family *Poaceae* and is popular for its edible starchy seeds. In India sorghum is known as *jowar***.** Sorghum is especially valued in hot and arid regions for its resistance to drought and heat. The colour of the sorghum was red with oval shape. The results for physical parameter presented in Table 4.1. As is evident from the same table the mean values for 1000 kernel weight, density and bulk density came out to be 31.73g, 1.25g and 0.87g/ml respectively. The porosity value attained as 30.20g/100g. Vannalli et al. (2008) reported thousand kernel weight of ten different varieties of Sorghum between the range of 25.59 to 41.01g which are in line with the present studies.

iv. Finger millet (*Eleusine coracana L.)*

It is one of the important millet grown extensively in various regions of India and Africa, constitutes as a staple food for the major chunk of the inhabitants of these countries. Even in India, it ranks sixth in production after wheat, rice, maize, sorghum and bajra. The colour of finger millet was found to be reddish brown with round shaped grains. The same table reflects the mean values for 1000 kernel weight, density and bulk density as 2.31g 1.36g/ml and 0.72g/ml respectively. The porosity was calculated as 46.94g/100g. Nazni and Bhuvaneswari (2015) reported the values for one thousand kernel weight 2.46±0.005g, which is on the higher side whereas, the value of bulk density reported as 0.70±0.01g/ml which is pretty closer to the present result. The difference could be because of high starch, low content of protein and fat in finger millet.

Table 4.1 Physical parameters of selected cereal crops

Parameters / Crops	Colour	Shape	1000 Kernel Weight. (g)	Density (g/ml)	Bulk Density (g/ml)	Porosity (g/100g)
Oat	Cream	Elongate spindle	26.95± 0.05	1.01± 0.005	0.58± 0.005	43.27± 0.49
Pearl Millet	Gray	Oval	9.05± 0.01	1.45± 0.02	0.72± 0.02	20.12±1.05
Sorghum	Red	Oval	31.73± 0.04	1.25± 0.02	0.87± 0.02	30.20± 1.35
Finger millet	Redish Brown	Round	2.31± 0.009	1.36± 0.005	0.72± 0.005	46.94± 0.57

4.1.2 Functional properties evaluation

Functional properties of food are the keys to verify their potential for food applications since these factors are related to the ability of products to absorb or dissolve in water at room temperature or heated, oil absorption during product development. The test samples were evaluated for functional parameters viz. water absorption index, water solubility index, water absorption capacity, oil absorption capacity, foaming capacity and foaming stability.

and results are presented in Table 4.2.

Functional parameters of selected cereal crops

i. Oat (*Avena sativa)*

A glance at Table 4.2 reveals the values of oat for functional properties as water absorption capacity (189.0), oil absorption capacity (205.00), foam capacity (18.00), foam stability (12.00), water solubility index (2.25g/g) and water absorption index (4.50) per cent respectively. Singh et al. (2015) studied the five varieties of oat grains and reported the results of water absorption capacity, oil absorption capacity, foaming capacity, emulsion capacity and emulsion stability between the range of 167-186, 189-222, 8-22, 41.6-56.9, 67.7-73.3 per cent respectively in OS-7, OS-6, OS-346, HFO-114. The varieties with high water absorption might have more hydrophilic constituents, such as polysaccharides as reported previously by Hodge and Osman (1976).

ii. Pearl millet (*Pennisetum glaucum*)

Table 4.2 depicts the values of pearl millet for functional properties as water absorption capacity (72.01), oil absorption capacity (84.21), foam capacity (27.00), foam stability(18.00), water solubility index (9.13g/g) and water absorption index (8.25) per cent respectively. Gull et al. (2015) reported the values for water solubility index, foam capacity and foaming stability in pearl millet as 4.13±0.61, 5.88±0.00 and 0.98 per cent respectively which are on the much lower side..This might be due to the protein denaturation caused by grinding. The same has been earlier reported by Lin et al. (1974) that the native proteins provide high foam stability than denatured protein.

iii. Sorghum (*Sorghum bicolour*)

Table 4.2 illustrates the values of sorghum for functional properties as water absorption capacity (61.03), oil absorption capacity (76.23), foam capacity (36.00), foam stability(25.00), water solubility index (2.83g/g) and water absorption index (0.74) per cent respectively. Olosunde et al. (2015) reported the functional properties of sorghum as water absorption capacity 2.49± 0.11, water solubility 2.56±0.23 per cent and oil absorption 0.79±0.17mg oil /g. The differences in oil binding capacities of different varieties could be attributed to variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil and thus enhance the capacity of cereals to bind oils. The same reason was explained by Adebowale and Lawal (2004) in the work. McWatters and Heaton (1979) also elaborate the ability of different cereals to absorb and retain water and oil may help improve binding of the structure, enhance flavour retention, improve mouthfeel and reduce moisture and fat losses of during processing operations The reduction in stability of foams could be attributed to the drainage of liquid from the lamellae accompanied by an increase and then rupture in the size of air bubbles responsible for foam formation Sathe et al. (1982). This gives credence to the present results.

iv. Finger millet (*Eleusine coracana L.)*

Table 4.2 represents the values of finger millet for functional properties as water absorption capacity (64.21), oil absorption capacity (78.23), foam capacity (63.00), foam stability(51.00), water solubility index (6.12g/g) and water absorption index (1.23) per cent respectively. Gull et al. (2015) reported the functional properties

of finger millet as water solubility index (7.73±1.80), foaming capacity (1.96±0.00) and foaming stability (0.97±0.01)ml. There is an advantage for best organoleptic characteristics of meal that high water and oil absorption capacity of the flour can positively influence the flavour, moisture and fat content in food. The low foam capacity and stability could be due to the protein denaturation caused by grinding. It has been reported by Lin et al. (1974) that the native proteins provide high foam stability than denatured protein.

Table 4.2 Functional parameters of selected cereal crops

Crops	Oat	Pearl Millet	Sorghum	Finger Millet
WAC %	189.00±0.02	72.01±0.49	61.03±0.01	64.21±0.02
OAC%	205.00±0.94	84.21±0.04	76.23±0.03	78.23±0.03
FC%	18.00±0.06	27.00±0.01	36.00±0.79	63.00±0.89
FS%	12.00±0.03	18.00±0.05	25.00±0.01	51.00±0.49
WSI (g/g)	2.25±0.003	9.13±0.01	2.83±0.02	6.12±0.02±0.69
WAI (%)	4.50±0.02	8.25±0.00	0.74±0.03	1.23±0.01

4.1.3 Chemical and nutritional evaluation

Chemical and nutritional evaluation of selected test crop *viz.* oat (*Avena sativa*), finger millet (*Eleusine coracana L.),* pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolour*), horse gram *(Macrotyloma uniflorum),* chick pea (*Cicer arietinum)* and rice bean (*Vigna umbellata*) was done which includes proximate composition, sugars, dietary fiber and minerals.

4.1.3.1. Chemical parameters of selected cereal crops

The crops under study were evaluated for different constituent's *viz.* moisture, ash, crude fat, crude fiber, protein and carbohydrates. Estimation of moisture is

widely used in testing the quality of food. As the dry matter in food materials is inversely related to the amount of moisture it contains and it is directly related to satbility, eating quality, nutritive value and processing requirments. Ash content gives an index to the mineral matter in food materials. Crude fat is the crude mixture of fat soluble materials present in samples whereas, crude fiber is the residue of plant materials remaining after solvent extraction followed by digestion with acid and alkali and the estimation of crude protein reflects that total nitrogenous and non nitrogenous protien present in the sample. Data pertaining to chemical composition of selected test crop is depicted in the pertinent table.

i. Oat (*Avena sativa)*

Table 4.3 depicts the values for moisture as 8.73, ash 3.5, fat 4.95, crude fiber 5.34, crude protein 14.69 and carbohydrate 62.79 per cent respectively. Vijayakumar et al. (2013) reported slightly higher values for moisture content i.e. 8.92 per cent in oat. Thereafter, Kaur and associates in the year 2014 also reported escalated values for moisture content i.e. the moisture content 10.07 ±0.06 per cent in oat which might be due to storage conditions. Singh et al. (2015) studied the five varieties of oat and reported the results of ash as 3.50, 2.60, 3.90, 3.40, 2.90 per cent in OS-7, OS-6, OS-346, HFO-114 and kent respectively which are in accordance to the present results. The results of present study for fat content are also close to the values reported by the Bilal et al. (2014) who reported 5.49 ±0.76 per cent fat content in oat. Chappalwar et al. (2013) reported crude fiber content in oat flour as 3.91 per cent which is much less.This difference might be due to varietal difference for stage of harvesting. Singh et al. (2015) studied the five varieties of oat and reported the results of protein as 12.90, 13.30, 13.60, 14.40, 13.90 in OS-7, OS-6, OS-346, HFO-114 and kent respectively. . This gives credence to the present findings. Chappalwar et al. (2013) reported carbohydrate in oat flour was 65.70 per cent which is higher to the present value. This difference might be due to the varietal variations or climatic conditions.

ii. Pearl millet (*Pennisetum glaucum*)

Table 4.3 illustrate the values of pearl millet for moisture , ash, fat , crude fiber, crude protein and carbohydrate as 9.53, 2.48, 4.93, 2.70, 12.03, 68.33 per cent

respectively. Christine and his co researchers in 2012 reported the slightly higher value of moisture i.e. 10.7 ± 0.20 per cent . In 2012 Christine and his co researchers attain a lower value i.e 1.6±0.06 per cent of ash in Pearl millet which was much less as compare to the test samples. Vanisha et al. (2011) reported the carbohydrate in the range of 57.00 to 69.00 per cent, the values obtained in the present study are in line. Thilagavathi et al. (2015) also reported the values of protein on lower side. These variations in some of the parameters might be due to the agro – climatic conditions and varietal differences.

iii. Sorghum (*Sorghum bicolour*)

Table 4.3 portray the values of sorghum for moisture as 7.25, ash 1.43, fat 2.67, crude fiber 2.35, crude protein 11.23 and carbohydrate 75.07 per cent respectively. Four local varieties of Sorghum were studied by Udachan et al. (2012) and reported the moisture (per cent) content as 8.10, 9.80, 9.99 & 8.5, crude fiber (per cent) content as 1.40, 2.70, 1.90, 1.58 and protein (per cent) content as 8.90 9.60 11.02 10.65 CSH-5, CSH-9 Dadar and Parbhani varieties respectively. Whereas Vanisha et al. (2011) reported the Per cent fat in Sorghum as 1.90 per cent and carbohydrate as 7.26 per cent. This is very close to the test crop. Slight changes might be due to agro-climatic or genetic makeup of the crop.

iv. Finger millet (*Eleusine coracana L.)*

Table 4.3 represents the values of finger millet for moisture as 8.47, ash 2.41, fat 2.00, crude fiber 3.63, crude protein 7.45 and carbohydrate 76.04 per cent respectively. Gunashree et al. (2014) reported 8±0.083 per cent moisture, 2.0±0.015 per cent ash content, 1.8±0.02 per cent fat content and 6.8 ± 0.01 per cent protein in Finger millet. The slight difference in values might be due to maturity at harvesting, condition of stored grains and it may be due to the genetic makeup of the crop.

Table 4.3 Chemical parameters of selected cereal crops (per cent)

Crop / Parameters	Oat	Pearl Millet	Sorghum	Finger Millet
Moisture	8.73±0.01	9.53±0.02	7.25±0.04	8.47±0.02
Ash	3.50±0.03	2.48±0.01	1.43±0.01	2.41±0.09
Crude Fat	4.95±0.03	4.93±0.03	2.67±0.01	2.00±0.05
Crude Fiber	5.34±0.03	2.70±0.02	2.35±0.04	3.63±0.02
Crude Protein	14.69±o.o3	12.03±0.09	11.23±0.02	7.45±0.005
Carbohydrate	62.79±0.04	68.33±0.14	75.07±0.09	76.04±0.06

4.3.1.2. Nutritional evaluation:

In the present study effort was made to estimate nutritional parameters *viz*. ADF, NDF, lignin, hemi cellulose, cellulose, total dietary fiber, total sugar, reducing sugars and non reducing sugars. In the crops under study the results thus obtained are illustrated in Table 4.4.

Nutritional parameters of selected cereal crops

i. Oat (*Avena sativa)*

A close scrutiny of data narrates the values of oat for ADF (2.02), NDF(6.86), lignin(0.39), hemicelluloses (4.91), cellulose (1.39), total dietary fiber (9.27), non reducing sugar (1.19), reducing sugar (0.51) and total sugar(1.71) per cent respectively. Nutan (2015) also reported the total soluble sugars, reducing sugars, non-reducing sugar as 1.68±0.09, 0.50±0.02, 1.18±0.01per cent respectively in oat which are in line with the present study. Dietary fiber is a sum of polysaccharides and lignin which are not hydrolyzed by the enzymes of the alimentary tract of man. Estimation of neutral detergent fiber gives cellulose, hemicelluloses and lignin. Kaur et.al (2014) reported, 2.00±0.41, 6.91±0.32, 0.60±0.20, 4.91±0.10, 1.40±0.61, 0.28±0.21 as ADF, NDF, ADL, hemi cellulose, cellulose and lignin in oat respectively which are in accordance to the test values. However, the difference in fiber constituents like lignin might be due to the maturity stages of the oat grains, the

middle lamella of the cell wall has more lignin than other parts so lignin content is more at early maturity stages than late maturity.

ii. Pearl millet (*Pennisetum glaucum*)

Same table represents the values of ADF, NDF, lignin, hemicelluloses, cellulose, total dietary fiber, total sugar, reducing sugar and non reducing sugar in pearl millet as 3.12, 5.56, 0.23, 2.44, 2.89, 8.91, 2.88, 0.77 and 2.11 per cent respectively. Devi et. al (2011) analyzed the twelve cereal grains and reported the total dietary fiber in pearl millet as 7.0 per cent which is lesser as compared to the present findings.This difference might be due to harvesting stage of maturity. Mamta (2015) reported the sugars in two varieties of pearl millet as total sugars, reducing sugars and non reducing sugars in HHB-223 and HHB-67 Improved 2.41±0.09, 0.48±0.05, 1.82±0.02 and 2.50±0.04, 0.59±0.03 and 1.93±0.07 per cent respectively, the slight variation in results might be due to genetic factors and varietal differences.

iii. Sorghum (*Sorghum bicolour*)

Table 4.4 represent the values of sorghum for ADF, NDF, lignin, hemicelluloses ,cellulose, total dietary fiber, total sugar, reducing sugar, non reducing sugar 5.53, 11.29, 1.10, 5.76, 4.43, 17.92, 2.14, 0.80 1.34 per cent respectively . National research council (1996) reported the ADF, NDF and lignin in sorghum grain as 5.9, 10.9 and 1.1 which is on the lower side of the present study, the difference in fiber constituents like might be due to the difference in maturity stages of the sorghum grains at harvesting.

iv. Finger millet (*Eleusine coracana L.)*

As it is evident from the Table 4.4 the per cent values for ADF, NDF, lignin, hemicelluloses, cellulose, total dietary fiber, total sugar, reducing sugar and non reducing sugar in finger millet as 5.86, 9.02, 0.30, 3.19, 5.56, 15.21, 1.69, 0.06, 1.63 per cent respectively. Nirmala et al. (2000) reported value of 1.5 per cent reducing sugar and 0.03 per cent non-reducing sugar in finger millet. Devi et. al (2011) analyzed the finger millet grains and repoted the total dietary fiber of finger millet 19.1 per cent. The values of the dietary fiber are on the lower side which might be due to the varietal variation and maturity at harvesting stage.

Table 4.4 Nutritional parameters of selected cereal crops (per cent)

Crop / Parameters	Oat	Pearl Millet	Sorghum	Finger millet
ADF	2.02±0.03	3.12±0.02	5.53±0.13	5.86±0.05
NDF	6.86±0.04	5.56±0.03	11.29±0.06	9.02±0.03
Lignin	0.39±0.005	0.23±0.02	1.10±0.02	0.30±0.01
Hemi Cellulose	4.91±0.02	2.44±0.04	5.76±0.16	3.19±0.09
Cellulose	1.39±0.01	2.89±0.02	4.43±0.15	5.56±0.04
Total Dietary Fiber	9.27±0.2	8.91±0.01	17.92±0.10	15.21±0.05
Total Sugar	1.71±0.01	2.88±0.17	2.14±0.03	1.69±0.03
Reducing Sugars	0.51±0.01	0.77±0.04	0.80±0.02	0.06±0.02
Non Reducing Sugars	1.19±0.01	2.11±0.13	1.34±0.02	1.63±0.01

4.3.1.3. Mineral evaluation

Selected test crops were evaluated for different mineral constituents and results thus obtained are represented in Table 4.5.

Mineral composition of selected cereal crops (mg/100g)

i. Oat (*Avena sativa)*

The test samples evaluated for minerals and the results are illustrated in Table 4.5. A glance at the table reveals that oat samples under test contained Ca, Mg & P at the tune of 78.05, 135.25, 381.02 mg/100g respectively. Whereas, the values for K, Fe, Zn and Na calculated as 379.46, 4.42, 3.03 and 7.95 mg/100g respectively. Sangwan et al. (2014) studied the mineral content in oat and reported the minerals contents in oat as calcium, iron, phosphorus, potassium, sodium, zinc, copper and manganese 84, 7.36, 276, 816, 669, 3, 6.19, 0.977 and 7.669mg respectively .The results are on the higher side in the present study. This might be due to the genetic

factor and environmental conditions prevailing in growing region which affect the minerals content.

ii. Pearl millet (*Pennisetum glaucum*)

The same table also presents the values for the same constituents in pearl millet another important crop of tribal area of Himachal. The values for Ca, Mg, P, K, Fe, Zn and Ma were established as 27.82, 124.23, 218.09, 39.01, 12.08, 3.03, 7.08 mg/100g respectively. Vanisha et al. (2011) studied the pearl millet from four different sources and found minerals contents in the range of 25 – 42 calcium; 296 phosphorous; 3 - 11 iron; 2.2 - 3.1 Zn; 5 - 10.9 sodium and 106 - 137 magnesium mg/100g. These results have slight variations with the present study, this could be due to agro-climatic conditions or varietal differences

iii. Sorghum (*Sorghum bicolour*)

Table 4.5 interpret the values of sorghum for minerals as Ca (22.56), Mg (112.09), P (208.35), K (302.06), Fe (3.84), Zn (1.32) and sodium (7.17) mg/100g respectively. Vanisha et al. (2011) studied the sorghum and found minerals content as in sorghum 25.00 Ca, 222.00 P, 4.10 Fe, 1.60 Zn, 7.30 Na and Mg 171 mg/100g respectively which is very close to the results obtained in test crop. Earlier Obilana (1996) also reported the results in support of present study as Ca 27.00, Cu 2.40, Fe 6.60, Mn 180.00, Mg 2.90, P 520.00, K 440.00, Na 14.00 and Zn 4.40 mg/100g with the slight variations to the present results. This might be due to agro-climatic conditions, varietal differences and soil health.

iv. Finger millet (*Eleusine coracana L.)*

Table 4.5 depicts the values of finger millet for minerals as Ca (269.54), Mg (343.00), P (8.21), K (5.10), Fe (5.0), Zn (2.81) and sodium (0.95) mg/100g respectively. Gunashree et al. (2014) analyzed the finger millet for mineral content and find the 280.60 Ca, 350 mg 71.00 Cu, 246.00 Mg, 4.97 Fe, 2.56 Zn, 5.34 K and Na 0.83 mg/100g respectively which are very close to the present results. Earlier, Obilana in 1996 also reported the mineral content in finger millet as 334.00 Ca; 0.50 Cu; 9.90 Fe, 190.00 Mn ; 1.9.00 Mg; 250.00 P; 314.00 K, 49.00 Na and Zn 1.5.00mg/100g repectively. Some variations might be due to agro-climatic conditions and varietal differences.

Table 4.5 Mineral composition of selected cereal crops (mg/100g)

Crops	Oat	Pearl Millet	Sorghum	Finger Millet
Ca	78.05±25.99	27.82±0.04	22.56±0.03	269.54±0.77
Mg	135.25±0.03	124.23±0.01	112.09±0.17	343.00±0.03
P	381.02±0.03	218.09±0.08	208.35±0.02	8.21±0.00
K	379.46±0.05	39.01±0.01	302.06±0.02	5.10±0.01
Fe	4.42±0.04	12.08±0.02	3.84±0.005	5.00±0.01
Zn	3.03±0.005	3.03±0.01	1.32±0.005	2.81±0.01
Na	7.95±0.05	7.08±0.03	7.17±0.02	0.95±0.01

4.3.1.4. Amino acid profiles of selected test crops

Quality of any protein depends upon its amino acid profile. Therefore, protein quality evaluation is done to evaluate the protein source for metabolic demand and overall efficiency of protein utilization on the basis of presence of essential amino acids.

Phenylalanine is categorized as essential and aromatic amino acid, required for synthesis of secondary metabolites like hormones, lignin and phenolic compounds. Sugars and phosphates produced during the metabolic pathway (like pentose phosphate pathway) can be utilized to form aromatic amino acids like phenylalanine and tyrosine (Tzin and Galili, 2010). In the 1985 edition of WHO report for "*Energy and Protein requirement*", histidine was recognized as essential amino acid due to its effect on hemoglobin (Kriengsinyos et al. 2002). Histidine deficient diet may lead to lower hemoglobin accompanied by rise in serum iron concentration (Kopple and Swendseid, 1975). Isoleucine, leucine and valine are the indispensible/essential branched chained amino acids, highly recommended for muscle tissue buildup.

Thereby, to understand the protein quality of test samples efforts were made to evaluate amino acid composition. The results thus obtained are presented in Table 4.6.

Amino acid profiles of selected cereal crops (µg/100g)

i. Oat (*Avena sativa)*

An effort was made to study the amino acid profile of oat. As is evident from the Table 4.6 the values for histidine, isolucine lucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, alanine, arginine, aspartic, asparagines, cystine, glutamic acid, glutamine, glycin, proline, serine and tyrosine are calculated as 670, 3352, 1777, 1822,720, 580, 3021, 672, 2180, 1034, 1288, 4015, ND, 790, 5072, ND, 795, 1290, 2092, 12900µg/100g respectively. Sangwan et al (2014) evaluated the amino acid content of one cup (156g) of oat and reported amino acid values as tryptophan (0.365), threonine (0.897), isolucine (1.083), lucine (2.003), lycine (1.094), methionine (0.487), cystine (0.636), phenylalanine (1.396), tyrosine (0.894), valine (1.462), arginine (1.860), histine (0.632), alanine (1.374), aspartic acid (2.259), glumatic acid (5.791), glycine (1.312), proline (1.457) and serine (1.170) g/100g respectively. The results have the variation with the present study which might be due to the condition of the soil, application of the nitrogen fertilizer at various stages of plant growth and the genetic makeover of the oat grains.

ii. Pearl millet (*Pennisetum glaucum*)

Same table depicts the amino acid profile of pearl millet and the values for histidine, isolucine lucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, alanine, arginine, aspartic, asparagines, cystine, glutamic acid, glutamine, glycine, proline, serine and tyrosine calculated as 1954, 6742, 10812, 1682, 2296, 3547, 6782, 1796, 6452, 4967, 3126, 10607, ND, 2967, 19792, ND, 2687, 5866, 5245, 3540µg/100g respectively. Amadeu et al. (2013) reported amino acid content of pearl millet as isoleucine (4.59) lucine (13.60), lysine (1.59), methonine (3.06), phenylolanine (6.27),threonine (3.68), valine (5.81), histidine (2.11), alanine (9.30), arginine (3.00), aspartic acid (7.71), cystine (0.45), glutamic acid (22.00) glycine (2.91) serine (4.56), tyrosine (2.44)and proline (5.54) g/100g. The results are in line to the present study.

iii. Sorghum (*Sorghum bicolour*)

Table 4.6 illustrates the amino acid profile of sorghum and the values for histidine, isolucine lucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, alanine, arginine, aspartic, asparagines, cystine, glutamic acid, glutamine, glycine, proline, serine and tyrosine as 1965, 679, 10911, 148, 2320, 3769, 6810, 1863, 6459, 5532, 3215, 10807, ND, 3108, 20272, ND, 2655, 5987, 5320, 3547µg/100g respectively. Awadalkareem et al. (2008) also evaluated the amino acid profile of sorghum flour and reported the results as 517.81, 204.72, 231.55, 995.86,72.22, 984.00, 504.85, 134.95, 411.73, 1230.76, 147.33, 443.47, 219.23, 105.75 and 877.22mg/100 for aspartic, thrionine, serine, glutamic, glycemic, alanine, valine, methionine, isolucine, tyrosine, phenylalanine, histidine, lysine and ammonia respectively. The variations in results might be due to the condition of the soil, application of the nitrogen fertilizer at various stages of plant growth and the genetic makeover of the sorghum grains

iv. Finger millet (*Eleusine coracana L.)*

Table 4.6 illustrates the amino acid profile of finger millet and the values for histidine, isolucine, lucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, alanine, arginine, aspartic, asparagines, cystine, glutamic acid, glutamine, glycin, proline, serine and tyrosine as 3800, 729, 1296, 1080, 154, 341, 584, 157, 784, 657, 1317, 1889, ND, 148, 2621, ND, 6321, 684, 839, 572µg/100g respectively. Thapliyal and Singh (2015) reported amino acid content in finger millet as 4.3 (isolucine), 10.8 (lucine), 2.2 (lysine), 2.3 (histidine), 6.0 (alanine), 3.4 (arginine), 5.7 (aspartic acid) 23.2 (glutamic acid), 3.3 (glysine), 5.3(serine), 3.6 (tyrosine) and 9.9 (prolein)g/100g. The variations involves might be due to the condition of the soil, application of the nitrogen fertilizer at various stages of plant growth and the genetic makeover of the finger millet grains

Table 4.6 Amino acid profile of selected cereal crops (µg/100g)

Sr.No.	Amino acid (µg/100g)	Oat	Pearl Millet	Sorghum	Finger Millet
1.	Histidine	670.00±0.03.	1954.00±0.01	1965.00±0.17	3800.00±.03
2.	Isolucine	3352.00±0.02	6742.00±0.08	679.00±0.13.	729.00±0.04
3.	Leucine	1777.00±0.08	10812.00±0.13	10911.00±0.0.14	1296.00±0.02
4.	Lysine	1822.00±0.05	1682.00±0.15	148.00±0.02.	1080.00±0.01
5.	Methionine	720.00±0.02	2296.00 ±0.93	2320.00±.0.02	154.00±0.04
6.	Phenylalanine	580.00±0.17	3547.00±0.18	3769.00±0.80	341.00±0.40
7.	Threonine	3021.00±0.03	6782.00±.0.02	6810.00±0.03	584.00±0.01
8.	Tryptophan	672.00±0.02	1796.00±070	1863.00±040	157.00±0.40
9.	Valine	2180.00±0.87.	6452.00±0.55	6459.00±0.58	784.00±0.02
10.	Alanine	1034.00±0.04	4967.00±0.01	5532.00±0.94.	657.00±0.03
11.	Arginine	1288.00±0.45	3126.00±0.68	3215.00±0.78	1317.00±0.69
12.	Aspartic	4015.00±094	10607.00±0.49	10807.00±079	1889.00±0.49
13.	Asparagine	ND	ND	ND	ND
14.	Cystine	790.00±0.87	2967.00±0.02	3108.00±0.04	148.00±0.03
15.	Glutamic acid	5072.00±0.02	19792.00±0.39	20272.00±0.39	2621.00±0.04
16.	Glutamine	ND	ND	ND	ND
17.	Glycin	795.00±0.78	2687.00±0.69	2655.00±0.93	6321.00±0.56
18.	Proline	1290.00±0.02	5866.00±0.08	5987.00±0.05	684.00±0.49
19.	Serine	2092.00±0.05	5245.00±0.04	5320.00±0.75	839.00±0.69
20.	Tyrosine	12900.00±0.01	3540.00±0.05	3547.00±0.89	572.00±0.03

4.1.4 Phyto-chemical evaluation

Saponins are known to produce inhibitory effect on inflammation. The characteristics which include the formation of foams in aqueous solutions, haemolytic activity, cholesterol binding properties and bitterness.

Phyto-chemical constituents of selected cereal crops (mg/100g)

i. Oat (*Avena sativa)*

Table 4.7 narrates the values for phyto chemicals of oat as saponin (2.30) and tannin (0.12)mg/100g. Kumar et al. (2015) studied the effect of relacing oat fodder with fresh and chopped oat leaves on *in vitro* rumen fermentation, digestibility and metabolizable energy and reported the total tannin content as 0.74±0.01 percent which is on the higher side of the present study. This could be due to the difference in colour of test sample because tannin content is affected by the colour of the test crops. Darker the colour more is the tannin content.

ii. Pearl millet (*Pennisetum glaucum*)

Table 4.7 illustrates the values for phyto chemicals of pearl millet as saponin (0.20) and tannin (228.00)mg/100g. Florence and Urooj (2014) studied the two varieties of pearl millet and reported the tannin content as 0.23± 0.01, 0.21± 0.02 in Kalukombu (K) and Maharashtra rabi bajra (MRB) respectively. Earlier, Eitayeb (2003) done nutritional evaluation of traditionally processe pearl millet and reported the tannin content in the range of 0.22 and 0.17 per cent for untreated samples of Gazira cultivar and Gadarif cultivar. There is slight variation in the results, this could be due to the presence of high protein content, saponin form the high molecular complex with proteins particularlary with casine and β casine is more susceptible and tannin content is affected by the colour of the test crops, darker the colour more is the tannin content.

iii. Sorghum (*Sorghum bicolour*)

Table 4.7 represents the values of sorghum for phyto chemicals as saponin (0.89) and tannin (1.55)mg/100g. Olosunde et al. (2015) analyzed the sorghum flour and reported the results of saponin and tannin as 0.83 and 1.96 mg/100g respectively. There are slight differences in the results this might be due to the high protein content and variation in the colour of sorghum cultivars.

iv. Finger millet (*Eleusine coracana L.)*

Table 4.7 describes the values in finger millet for phyto chemicals as saponin (5.29) and tannin (1.73)mg/100g. Folasad (2011) studied the processed and unprocessed finger millet grains and reported the results of saponin and tannin content in unprocessed seed as 5.40±.00 and 1.69±0.10 mg/100g. The slight differences in the results could be due to the difference in colour of finger millet cultivars coupled with variation in protein content.

Table 4.7 Phyto-chemical constituents of selected cereal crops *(mg/100g)*

Crops	**Oat**	**Pearl Millet**	**Sorghum**	**Finger Millet**
Saponin (mg/100g)	2.30±0.01	0.20±0.02	0.89±0.02	5.29±0.02
Tannin (mg/100g)	0.12±0.00	228.00±0.08	1.55±1.12	1.73±0.05

4.3.1.5. Starch and glycemic index evaluation of selected cereal crops (g/100g)

i. Oat (*Avena sativa)*

Table 4.8 depicts the values of starch (9.43), resistant starch (2.69), amylose (18.20) and glycemic index (40.78) per cent respectively for oat. Stevenson et al. (2007), reported starch content in oat Kernel and amylose content as 7.88 and 33.6per cent respectively. The results of amylose content are on the lower side to the present study. This difference might be due to the amount of amylose present in the oat granules which significantly affects the physico-chemical and functional properties of starch. The amylose content can vary within the same botanical variety because of differences in geographic origin and culture conditions and the capacity of amylose molecules to form lipid complexes, prevents starch leaching.

ii. Pearl millet (*Pennisetum glaucum*)

Table 4.8 represent the values of starch (50.73), resistant starch (2.50), amylose (15.56) and glycemic index (40.34) per cent respectively for pearl millet. Rao et al.

(2017) reported starch content in pearl millet as 55.21±2.57 g/100g. Thilagavathi et al. (2015) reported the starch and amylose content in pearl millet as 56.82 ±1.18 and 22.18±0.39 g/100g respectively. The results of the present study are on the lower side this could be due to the maturity of the crop at harvesting couple with the varietal differences.

iii. Sorghum (*Sorghum bicolour*)

Table 4.8 interprets the values of starch (68.09), resistant starch (1.74), amylose (12.37) and glycemic index (40.18) per cent respectively for sorghum. Evaluation of starch, resistant starch and amylose content was also done by Nathakattur et al. in 2013 and they observed the values in red sorghum as 75.5, 3.9 and 24.5 respectively which are on the higher side to the present study. This might be due to the varietal differences and maturity of the crop.

iv. Finger millet (*Eleusine coracana L.)*

Table 4.8 represents the values of starch (57.53), resistant starch (2.38), amylose (12.62) and glycemic index (40.53) per cent respectively for finger milet. Jayawardana et al. (2019) studied the dietary fiber and starch fractions of fingermillet varieties cultivated in Sri Lanka and repoted the resistant starch and amylose in the range of 3.75 – 4.58 and 11.99 – 13.99 per cent respectively. The starch contect was investigated by Devi et al. in 2011 and reported as 56.1 per cent which gives credence to the present study.

Table 4.8 Starch and glycemic index evaluation of selected cereal crops (g/100g)

Crops	**Oat**	**Pearl Millet**	**Sorghum**	**Finger Millet**
Starch	9.43±0.04	50.73±0.02	68.09±0.94	57.53±0.49
Resistant starch	2.69±0.05	2.50±0.05	1.74±0.39	2.38±0.05
Amylose	18.20±0.49	15.56±0.69	12.37±0.84	12.62±0.79
Glycemic index	40.78±0.01	40.34±0.01	40.18±0.94	40.53±0.01

4.1.1. Physical parameters of selected pulse crops

i. Horse gram *(Macrotyloma uniflorum)*

Horse gram is an important crop of south India, total origin and its grains are generally used for human consumption as '*dal*' as well as in preparation of so called '*rasam'* and also as a concentrated feed for cattles. Horse gram (*Macrotyloma uniflorum*, previously called *Dolichos biflorus)* is a minor, under-exploited legume of tropics and sub-tropics grown mostly under dry-land agriculture. The colour of horse gram was observed as black with flat and ellipsoidal shape. The Table 4.9 shows the mean value for 1000 kernel weight 32.69g, density 1.39g/ml and bulk density 0.79g/ml in the sample. In the same sample the value for porosity is calculated as 43.32 g/100g. Hundred seed weight, density and bulk density of kulthi was observed by Bhokre and Joshi (2015) as 6.82g, 1.24 and 0.786g/ml respectively. The results for density and bulk desity are in line with the present study however, the result for one thousand kernel weight is lower side in the present study which could be due to the difference in size of the grain and maturity of the grain.

ii. Chick pea (*Cicer arietinum)*

Chick pea belongs to the family *Fabaceae* is an annual grain legume or "pulse crop" that is used extensively for human consumption. The seeds of chick peas were pale creamish colour with irregular shape. A glance at Table 4.9 reveals that the values for thousand kernel weight density, bulk density and porosity as 391g, 2.81g/ml, 0.80g/ml and 43.32 g/100g respectively. Average one thousand kernel weight of fourteen varieties of chick pea was reported between the range of 400 – 800g by Carla et al. (2013) which is slightly on the higher side. This slight variation may be due to varietal, agro-climatic conditions and maturity of the seed. Earlier in 2010, Kilican and Guner also reported the thousand kernel weight, bulk density and density as 383g, 741.50 and 1390.00kg/m^3 respectively which are close to present study but the porosity 46.50 per cent which is on lower sidein comparision to present results. This might be due to the size and molecular arrangement of the chick pea grain or it may be due to the difference in genetic makeover.

iii. Rice bean (*Vigna umbellata*)

Rice bean is a warm-season annual crop grown mainly as a dried pulse, It is also important as a folder and as a green manure. The dried seeds are highly nutritious and

good source of protein is high in lysine which makes it excellent addition to a cereal-based diet. The test samples were of pale green colour with cylindrical shape. The data presented in Table 4.9 reveals that the value for 1000 kernel weight, density, bulk density and porosity came out to be 191.00g, 1.45, 0.72g/ml and 50.12 per cent respectively. Joshi et al. (2007) studied thousand kernel weight of rice bean collected in different years and reported that at late maturity stage the weight ranges from 66 – 234g. Thousand kernel weight, density, bulk desity and porosity of rice bean varieties also studied by Bepray et al. in 2018 and reported as in range of 57.64 – 118.72g, 1138.40 – 1388.79, 820 – 877kg/m^3 and 26 – 40.57 per cent respectively. The results are very close to present study; however, values for porosity are on the higher sides which might be due to because of high starch content in rice bean.

Table 4.9 Physical parameters of selected pulse crops

Parameters / Crops	Colour	Shape	1000 Kernel Weight (g)	Density (g/ml)	Bulk Density (g/ml)	Porosity (g/100g)
Horse Gram	Black	Flat, ellipsoidal	32.69±0.25	1.39±0.03	0.79±0.04	43.32±1.45
Chick Pea	Pale cream	Irregular	391.00±2.16	2.81.00±0.01	0.80±0.005	71.44±0.18
Rice Bean	Pale Green	Cylinderical	191.00±2.16	1.45±0.02	0.72±0.02	50.12±1.05

4.1.2. Functional parameters of selected pulse crops

i. Horse gram *(Macrotyloma uniflorum)*

Table 4.10 illustrates the values of functional properties in horse gram as water absorption capacity (62.38), oil absorption capacity (80.85), foam capacity (47.00), foam stability(37.00), water solubility index (6.53g/g) and water absorption index (7.24) per cent respectively. Sreerama et al. (2007) reported the functional properties of horse gram as water solubility index (7.6±0.5), water absorption capacity

(135.8±3.8), oil absorption capacity (74.6±1.8), foaming capacity (45.0±1.8), foam stability (38.0±1.5), Emulsion activity (52.6±1.8) and emulsion stability (48.2±0.9) per cent. The differences in oil binding capacities of different varieties could be attributed to variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil and thus enhance the capacity of cereals to bind oils

ii. Chick pea (*Cicer arietinum)*

Table 4.10 deicts the values of chick pea for functional properties as water absorption capacity (73.38), oil absorption capacity (86.05), foam capacity (54.00), foam stability (45.00), water solubility index (23.64g/g) and water absorption index (1.72) per cent respectively. Abu- salem and Abu Arab (2011) reported functional properties of chick pea as water absorption index (1.90±0.02) water solubility 27.94±3.0 per cent this gives credence to the water solubility index but water absorption index highly variable this might be due to the ability of different chick pea varieties to absorb and retain water and oil may help improve binding of the structure, enhance flavour retention, improve mouthfeel and reduce moisture and fat losses of during processing operations.

iii. Rice bean (*Vigna umbellata*)

Table 4.10 depicts the values of ricebean for functional properties as water absorption capacity (63.00), oil absorption capacity (74.54), foam capacity (45.00), foam stability (36.00), water solubility index (2.83g/g) and water absorption index

Table 4.10 Functional parameters of selected pulse crops

Crops	Horse Gram	Chick Pea	Rice Bean
WAC %	62.38±0.01	73.38±0.94	63.00±0.01
OAC %	80.85±0.02	86.05±0.02	74.54±0.95
FC %	47.00±0.69	54.00±0.86	45.00±0.63
FS %	37.00±0.02	45.00±0.03	36.00±0.01
WSI (g/g)	6.53±0.02	23.64±0.08	2.83±0.02
WAI (%)	7.24±0.00	1.72±0.02	0.74±0.02

(0.74) per cent respectively. Hamid et al. (2015) studied the two varieties of *Vigna* genus and *V. unguiculata* species red and black and reported the water absorption capacity, oil absoption capacity, foaming capacity and foaming stability as 1.22±0.07 & 1.39±0.16, 0.72±0.01 & 0.71±0.04, 198.67±2.31 & 75.53.0.50 and 84.85±0.26 &78.83±0.29 per cent for red and black species respectively. These results are on the higher side to the present study which might be due to the protein denaturation in test crops caused by grinding.

4.1.3 Chemical and nutritional parameters of selected Pulse Crops

4.1.3.1 Chemical parameters of selected Pulse Crops

i. Horse gram *(Macrotyloma uniflorum)*

As is evident from the Table 4.11 the per cent values for moisture, ash , fat, crude fiber, crude protein and carbohydrate in horse gram are calculated as 6.65, 3.45, 1.80, 5.40 ,21.28 and 61.42 per cent respectively. Jain et al. (2012) studied the two varieties of *kulthi* and repoteted the per cent ash content as 3.08g, 2.97g in AK21 and AK42 respectively. Thilagavathi et al. (2015) reported the moisture content in the same crop as 10.82±0.33, fiber content as 5.64 ± 0.33 and protein content as 21.25 ± 0.67 per cent; this gives credence to the present findings. Sreerama et al. (2011) analyzed horse gram and calculated the fat content as 4.8±0.1 and carbohydrate content 61.01±1.8 per cent which is much less to the present study. All these variations in results might be due to varietal, genetic and agro – climatic conditions.

ii. Chick pea (*Cicer arietinum)*

Table 4.11 depicts the values of chick pea for moisture as 7.43, ash 2.83, fat 5.05, crude fiber 3.84, crude protein 22.36 and carbohydrate 58.49 per cent respectively. Ahmad and Kumar (2014) reported 8.40±0.50 per cent moisture content, 2.97±0.19 per cent ash and 24.61±1.37per cent protein content in chick pea. Sreerama et al (2011) analyzed chick pea and obtained the value for fat content as 4.8±0.1 per cent. Sharma et al. (2013) studied nine different cultivars of chick pea in their dried state which were procured from 'Sardar Vallabhbhai Patel University of Agriculture and Technology', Meerut, India and reported the results of crude fiber in five desi types (dark brown) K-850, PUSA-1103, PUSA-362, JG-62, JG-74 as 5.8±0.26,

4.4±0.47, 5.7±0.20, 3.5±0.45, 4.9±0.10 per cent respectively and in four kabuli types (white) PUSA-1105, PUSA1108, PUSA-1088, PUSA-1053 as 3.8±0.10, 3.4±0.17, 4.1±0.03 and 3.7±0.02 per cent respectively. The variation in values might be due to agro-climatic conditions. Though the results obtained in present work is in accordance to the values reported in literature.

iii. Rice bean (*Vigna umbellata*)

From the same table it is clear that values of rice bean obtained for moisture, ash, fat, crude fiber, crude protein and carbohydrate in the tune of 9.53, 2.48, 1.93, 3.40, 23.03, 67.33 per cent respectively. The moisture content in rice bean observed by Ren –Shun (2012) was 10.65±0.70 per cent, ash content 2.85±0.20 per cent, fat content1.69±0.09 per cent and protein content 25.99 ± 1.26 per cent. All the results are in line with the results of present study. In rice bean the crude fiber as reported by Bajaj (2014) of four different varieties of rice bean, viz., 'RBL-1', 'RBL-6', 'RBL-35', 'RBL-50', was 3.43±0.27, 3.60±0.42, 3.40±0.29 and 3.00±0.35 per cent and these results are in line with the present study. Slight changes might be due to the agro- climatic and varietal changes.

Table 4.11 Chemical parameters of selected pulse crops (per cent)

Crops / Parameters	Horse Gram	Chick Pea	Rice Bean
Crop Moisture	6.65±0.02	7.43±0.02	9.53±0.02
Ash	3.45±0.01	2.83±0.02	2.48±0.01
Crude Fat	1.80±0.02	5.05±0.04	1.93±0.03
Crude Fiber	5.40±0.04	3.84±0.03	3.40±0.02
Crude Protein	21.28±0.38	22.36±0.02	23.03±0.08
Carbohydrate	61.42±0.39	58.49±0.11	67.33±0.13

4.1.3.2 Nutritional parameter of selected pulse crops (per cent)

i. Horse gram *(Macrotyloma uniflorum)*

Table 4.12 represents the values of horse gram for ADF, NDF, lignin, hemicelluloses, cellulose, total dietary fiber, total sugar, reducing sugar and non reducing sugar in finger millet as 6.37, 9.17, 0.46, 2.80, 5.91, 15.99, 1.91, 0.81 and 1.10 per cent respectively. Kumar et al.2014 studied the dietary fiber of raw horse gram and reported the values as 22.47±0.07 per cent which is on the higher side as compare to the present study. This might me due to the difference in maturity stage of the horse gram at the time of harvesting.

ii. Chick pea (*Cicer arietinum)*

Table 4.12 interprets the values of chick pea for ADF (5.98), NDF(16.02), lignin(0.38), hemicelluloses (10.04), cellulose (5.61), total dietary fiber (22.38), non reducing sugar (5.23), reducing sugar (1.33) and total sugar (6.56) per cent respectively. Garg and Sabharwal (2014) observed total soluble sugars, reducing sugars, non-reducing sugars in two cultivars of chickpeas as HC-1 9.46a±0.39, 1.33a±0.21, 8.13a±0.19 and C-235 9.20a±0.70, 1.52a±0.30, 7.68a±0.40 per cent respectively. Hidalgo et al. (1997) reported NDF, ADF, cellulose, hemicellulose and lignin content in chick pea as 17.40±1.55, 6.59±0.37, 5.86±0.34, 11.54 and 0.73±0.10 per cent respectively in chick pea which are on the higher side of the test crops the difference in results might be due to the varietal variation and maturity at harvesting stage of chick pea pulse grains.

iii. Rice bean (*Vigna umbellata*)

Table 4.12 represents the values of rice bean for ADF (3.12), NDF(5.56), lignin(0.23), hemicelluloses (1.44), cellulose (2.89), total dietary fiber (7.91), non reducing sugar (2.11), reducing sugar (0.77) and total sugar (2.55) per cent respectively. In 2013, Katoch studied the nutritional potential of rice bean and reported the dietary fiber of sixteen genotypes of rice bean in the range of 4.11 – 5.56 per cent which is on the lower side to the present study. This slight difference could be due to the variation in variety and stage of maturity at the time of harvesting.

Table 4.12 Nutritional parameter of selected pulse crops (per cent)

Crop / Parameters	Horse Gram	Chick Pea	Rice Bean
ADF	6.37±0.05	5.98±0.12	3.12±0.01
NDF	9.17±0.02	16.02±0.14	5.56±0.03
Lignin	0.46±0.06	0.38±0.01	0.23±0.02
Hemi Cellulose	2.80±0.06	10.04±0.16	1.44±o.o4
Cellulose	5.91±0.07	5.61±0.11	2.89±0.02
Total Dietary Fiber	15.99±0.03	22.38±0.21	7.91±0.01
Total Sugar	1.91±0.06	6.56±0.22	2.55±0.74
Reducing Sugars	0.81±0.03	1.33±0.11	0.77±0.03
Non Reducing Sugars	1.10±0.02	5.23±0.09	2.11±0.13

4.1.3.3 Mineral evaluation of selected pulse crops (mg/100g)

i. Horse gram *(Macrotyloma uniflorum)*

Table 4.13 represents the values of minerals in horse gram i.e., Ca, Mg, P, K, Fe, Zn and sodium calculated as 289.32, 160.73, 295.81, 370.07, 6.97, 3.29 and 7.95 mg/100g respectively. Thilagavathi et al. (2015) reported the minerals content of horse gram as 295.32 ± 3.19 Ca, 6.94 ± 0.16 Fe, 298.72 ± 8.88 P, 165.34 ± 2.16 Mg, 3.92 ± 0.12 Mn, 16.65 ±0.69 Na, 367.73 ± 13.91 K, 2.47 ± 0.02 Cu and 3.47 ± 0.14 mg/100g Zn respectively which is on the higher side of test crops. These differences might due to the different in genetic factor and soil conditions prevailing in growing region affect the minerals content.

ii. Chick pea (*Cicer arietinum)*

Table 4.13 interprets the values of chick pea for minerals as Ca (156.13), Mg (162.21), P (695.1), K (670.14), Fe (7.15), Zn (3.58) and sodium (146.01) mg/100g respectively. Salem et al. (2011) reported minerals in chick pea as K (771.77), Ca

(156.13), Na (147.34), Mg (152.58), Cu (0.98), and Fe (6.85), Zn (3.83) repectively mg/100 g. There are slight differences in comparison to present studies. This could be due to the varietal variations and climatic conditions in which the crop was grown.

iii. Rice bean (*Vigna umbellata*)

Table 4.13 describes the values of rice bean for minerals as Ca (485.11), Mg (345.36), P (531.36), K (622.98), Fe (5.54), Zn (2.48) and Na (315.25) mg/100g respectively. Katoch (2013) studied the nutritional potential of rice bean and he reported the mineral content of sixteen genotypes of rice bean in the range of Ca 466 – 598; Mg 299 – 369; P 153 – 573; K 1452 – 1752; Fe 6.13 – 9.25; Zn 2.45 – 3.56 and sodium 276 – 347 mg/100g, slight difference in results might be due to be due to the soil health.

Table 4.13 Mineral evaluation of selected pulse crops (mg/100g)

Crops	Horse Gram	Chick Pea	Rice Bean
Ca	289.32±2.38	156.13±0.02	485.11±0.005
Mg	160.73±0.17	162.21±0.005	345.36±0.01
P	295.81±0.13	695.1±0.00	531.36±0.04
K	370.07±0.12	670.14±0.01	622.98±0.07
Fe	6.97±0.01	7.15±0.02	5.54±0.02
Zn	3.29±0.02	3.58±0.04	2.48±0.01
Na	7.95±0.01	146.01±0.07	315.25±0.23

4.1.3.4 Amino acid profiles of selected pulse crops (µg/100g)

Quality of any protein depends upon its amino acid profile. Therefore, protein quality evaluation is done to evaluate the protein source for metabolic demand and overall efficiency of protein utilization on the basis of presence of essential amino acids.

Phenylalanine is categorized as essential and aromatic amino acid, required for synthesis of secondary metabolites like hormones, lignin and phenolic compounds. Sugars and phosphates produced during the metabolic pathway (like pentose

phosphate pathway) can be utilized to form aromatic amino acids like phenylalanine and tyrosine (Tzin and Galili, 2010). In the 1985 edition of WHO report for "*Energy and Protein requirement*", histidine was recognized as essential amino acid due to its effect on hemoglobin (Kriengsinyos et al. 2002). Histidine deficient diet may lead to lower hemoglobin accompanied by rise in serum iron concentration (Kopple and Swendseid, 1975). Isoleucine, leucine and valine are the indispensible/essential branched chained amino acids, highly recommended for muscle tissue buildup.

Thereby, to understand the protein quality of test samples efforts were made to evaluate amino acid composition. The results thus obtained are presented in Table 4.14.

i. Horse gram *(Macrotyloma uniflorum)*

Table 4.14 illustrates the amino acid profile of horse gram and the values for histidine, isolucine lucine, lysine, methionine, phynile alanine, threonine, tryptophan, valine, alanine, arginine, aspartic, asparagines, cystine, glutamic acid, glutamine, glycin, proline, serine and tyrosine as 2041.00, 6789.00, 11940.00, 94912.00, 2125.00, 3084.00, 6784.00, 2019.00, 6042.00, 5536.00, 3281.00, 18891, ND, 3406.00, 21416.00, ND, 2794.00, 5480.00, 4979.00, 3081.00µg/100g respectively. Kamboj and Nanda (2017) reported the amino acid content of horse gram as arginine (530), histidine (190), lysine (520), tryptophan (70), phenylalanine (380), methionine (70), cystine (130), thyronine (230), lucine (540), isolucine (370) and valine (390) mg/g. The results have the variation with the present study these variations might be due to the condition of the soil, application of the nitrogen fertilizer at various stages of plant growth and the genetic makeover of the sorghum grains

ii. Chick pea (*Cicer arietinum)*

Table 4.14 illustrates the amino acid profile of chick pea and the values for histidine, isolucine lucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, alanine, arginine, aspartic, asparagines, cystine, glutamic acid, glutamine, glycin, proline, serine and tyrosine as 1960.00, 6071.00, 1042.00, 9187.00, 2019.00, 3405.00, 6810.00, 1862.00, 6519.00, 5167.00, 3157.00, 10908.00, ND, 3200.00, 21100.00, ND, 2652.00, 5081.00, 5167.00, 3209.00µg/100g respectively. Arab et al. (2010) reported amino acid content of chick pea as leucine (7.59), Isolucine (4.76), lysine (6.00), methronine (1.54), henyl alonine (5.57), theronine (3.89), valine (5.60),

cystine (1.36), tyrosine (3.58), alanine (4.88), arginine (7.82), aspartic (acid (11.18), glumatic acid (18.05), glycine (4.30), histidine (2.96), protein 4.68 and serine as 4.77 g/100g. The results have the variation with the present study these variations might be due to the condition of the soil, application of the nitrogen fertilizer at various stages of plant growth and the genetic makeover of the sorghum grains

Table 4.14 Amino acid profiles of selected pulse crops (µg/100g)

Sr.No.	Amino acid (µg/100g)	Horse Gram	Chick Pea	Rice Bean
1.	**Histidine**	2041.00±0.01	1960.00±0.95	3438.00±0.02
2.	**Isolucine**	6789.00±0.05	6071.00±0.94	140.00±0.79
3.	**Leucine**	11941.00±0.95	1042.00±0.01	5158.00±0.03
4.	**Lysine**	94912.00±0.01	9187.00±0.01	8164.00±0.02
5.	**Methionine**	2125.00±0.69	2019.00±0.89	6837.00±0.04
6.	**Phenylalanine**	3084.00±0.01	3405.00±0.02	1070.00±0.01
7.	**Threonine**	6784.00±0.69	6810.00±0.7.89	4194.00±0.79
8.	**Tryptophan**	2019.00±0.89	1862.00±0.95	1273.00±0.69
9.	**Valine**	6042.00±0.02	6519.00±0.01	4153.00±0.95
10.	**Alanine**	5536.00±0.08	5167.00±0.05	7717.00±0.03
11.	**Arginine**	3281.00±0.03	3157.00±0.02	4023.00±0.59
12.	**Aspartic**	18891.00±0.01	10908.00±0.05	6886.00±0.05
13.	**Asparagine**	ND	ND	ND
14.	**Cystine**	3406.00±0.02	3200.00±0.01	2504.00±0.08
15.	**Glutamic acid**	21416.00±0.95	21100.00±0.03	19016.00±0.039
16.	**Glutamine**	ND	ND	ND
17.	**Glycine**	2794.00±0.95	2652.00±0.01	3672.00±0.05
18.	**Proline**	5480.00±0.02	5081.00±0.04	5292.00±0.79
19.	**Serine**	4979.00±0.02	5167.00±0.03	5455.00±0.2
20.	**Tyrosine**	3081.00±0.01	3209.00±0.94	4155.00±0.01

iii. Rice bean (*Vigna umbellata*)

Table 4.14 illustrates the amino acid profile of rice bean and the values for histidine, isolucine lucine, lysine, methionine, phynile alanine, threonine, tryptophan, valine, alanine, arginine, aspartic, asparagines, cystine, glutamic acid, glutamine, glycin, proline, serine and tyrosine as 3438.00, 140.00, 5158.00, 8164.00, 6837.00, 1070.00, 4194.00, 1273.00, 4153.00, 7717.00, 4023.00, 6886.00, ND, 2504.00, 19016.00, ND, 3672.00, 5292.00, 5455.00, 4155.00µg/100g respectively. In 2013 Katoch studied the nutritional potential of rice bean and he reported the amino acid of sixteen genotypes of rice bean with slight variation, these variations might be due to the condition of the soil, application of the nitrogen fertilizer at various stages of plant growth and the genetic makeover of the sorghum grains

4.1.4 Phyto-chemical constituents of selected pulse crops *(mg/100g)*

i. Horse gram *(Macrotyloma uniflorum)*

Table 4.15 depicts the values of horse gram for phyto chemicals as saponin (0.11) and tannin (107.00)mg/100g. Marimuthu and krishnamoorthi (2013) studied 3 underutilized crops jack bean, lima bean and horse gram and he reported the saponin and tannin content of the crops as 0.520±0.02, 0.912±0.21, 0.152±0.12, 0.232±0.42 and 0.112±0.10, 0.104±0.03 g/100g respectively. There is slight variation in the results this could be due to the presence of high protein content, saponin form the high molecular complex with proteins particularlary, with casine, β casine is more susceptible and tannin content is affected by the colour of the test crops darker the colour more is the tannin content.

ii. Chick pea (*Cicer arietinum)*

Table 4.15 interpret the values of chick pea for phyto chemicals as saponin (4.78) and tannin (0.95) mg/100g. Alajaji and Eladaway (2006) analyzed nutritional composition of chick pea (*Cicer arietinum*) as affected by microwave cooking and other traditional cooking methods and find out saponin and tannin in raw chick pea as 0.91±0.10, 4.85±0.05 mg/100g respectively. There is slight variation in the results this could be due to the presence of high protein content, saponin form the high molecular complex with proteins particularlary, with casine, β casine is more susceptible and tannin content is affected by the colour of the test crops darker the colour more is the tannin content.

iii. **Rice bean (*Vigna umbellata*)**

Table 4.15 narrate the values of rice bean for phyto chemicals as saponin (0.20) and tannin (228.0)mg/100g. Shweta et al. (2017) studied the proximate and anti- nutritional compostion of under utilized and common *Vigna* species of Himachal Pradesh and reported the saponin content as 2.54 per cent which is on the higher side to the present study, this might be due to the varietal difference and presence of high protein content because saponin form the high molecular complex with proteins particularlary, with casine and β casine .

Table 4.15 Phyto-chemical constituents of selected pulse crops *(mg/100g)*

Crops	**Horse Gram**	**Chick Pea**	**Rice Bean**
Saponin (mg/100g)	0.11±0.005	4.78±0.08	0.20±0.02
Tannin (mg/100g)	107.00±3.00	0.95±0.05	228.00±2.08

4.1.3.5 Starch and glycemic index evaluation of selected pulse crops (g/100g)

i. Horse gram *(Macrotyloma uniflorum)*

Table 4.16 illustrate the values of starch (25.48), resistant starch (2.19), Amylose (12.34) and glycemic index (40.28) per cent respectively for horse gram. Thilagavathi et al. (2015) reported the starch and amylose content of horse gram as 28.62±1.11 and 12.46±0.20 g/100g. Sreerama et al. (2012) reported the resistant starch content of horse gram as 2.2±0.2g/100g & Marimuthoo and Krishnamoorthi (2013) reported the resistant starch content of horse gram as 2.15±0.20 g/100g Thus the results gives the credence to the present study.

ii. Chick pea (*Cicer arietinum)*

Table 4.16 narrate the values of starch (44.70), resistant starch (1.85), amylose (13.32) and glycemic index (40.23) per cent respectively for chick pea. Alajaji et al. (2006) reported the starch content of chick pea as 36.01±0.60 g/100g. Jukanti et al. (2012) reported the amylose content of chick pea as 30-40 per cent. The results of amylose content is on the lower side to the present study this difference might be due to the amount of amylose present in the granule significantly affects the

physicochemical and functional properties of starch. The amylose content can vary within the same botanical variety because of differences in geographic origin and culture conditions and the capacity of amylose molecules to form lipid complexes, prevents starch leaching.

iii. Rice bean (*Vigna umbellata*)

Table 4.16 narrates the values of starch (35.47), resistant starch (2.58), Amylose (5.44) and glycemic index (41.36) per cent respectively for rice bean. Ren et al. (2011 also studied the starch content of the rice bean varieties of China and he found the value as 46.42 per cent which is on the higher side which might be due to the difference in maturity stage at harvest coupled with the varietal variations.

Table 4.16 Starch and glycemic index evaluation of selected pulse crops (g/100g)

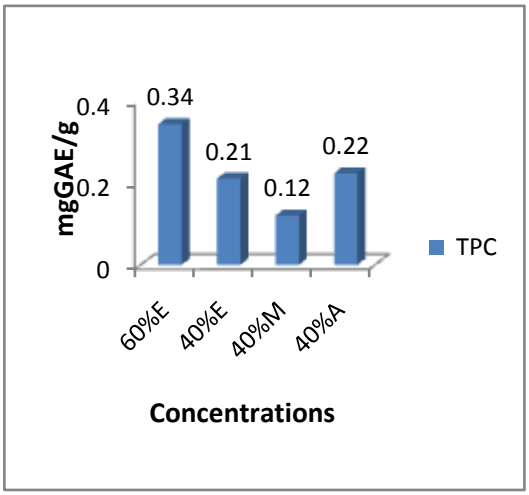
Crops	**Horse Gram**	**Chick Pea**	**Rice Bean**
Starch	25.48±0.69S	44.70±0.39	35.47±0.69
Resistant Starch	2.19±0.89	1.85±0.49	2.58±0.78
Amylose	12.34±0.03	13.32±0.02	5.44±0.69
Glycemic Index	40.28±0.01	40.23±0.01	41.36±0.95

4.1.5 Antioxidant activity evaluation

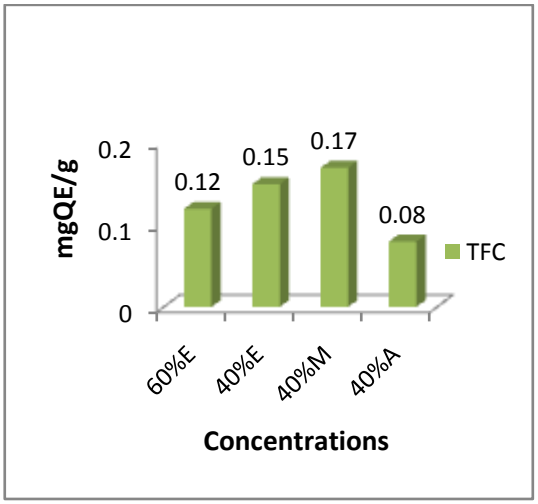
Antioxidant constituents of the plant material act as radical scavengers and helps in converting the radicals to less reactive species. The presences of natural antioxidants inhibits lipid peroxidation in foods, thereby results in improvement of quality and safety of food product as well as protect the human body from various diseases associated with ageing (Cuerda et al., 2011).

i. Oat (*Avena sativa)*

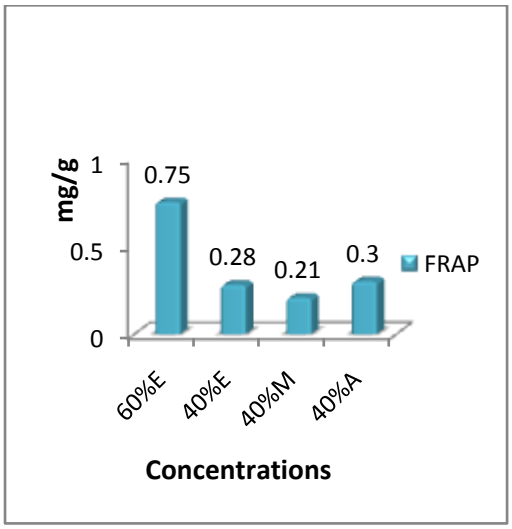
There is significant effect with all the solvents in total phenolic contents of oat. The difference is also significant with all the solvent in total flavonoid content of oat. In FRAP evaluation the difference between the FRAP contents treated with all the four concentration (60 per cent ethanol, 40 per cent ethanol, 40 per cent methanol and 40 per cent acetone) of various solvents is significant but the difference between 40



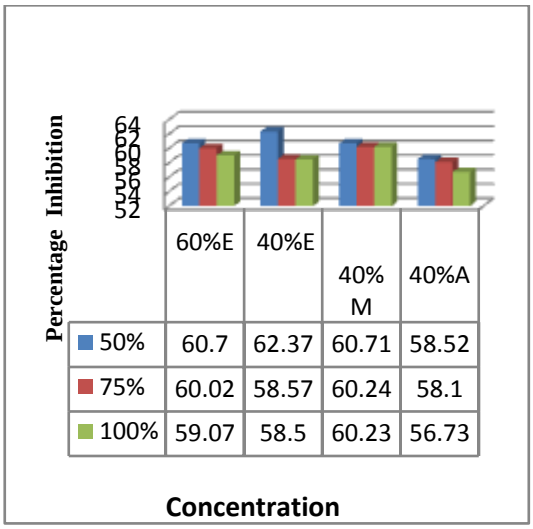
Total Phenolic Content (mgGAE/g)



Total Flavonoid Content (mgQE/g)



Ferric Reducing Antioxidant power (mg/g)



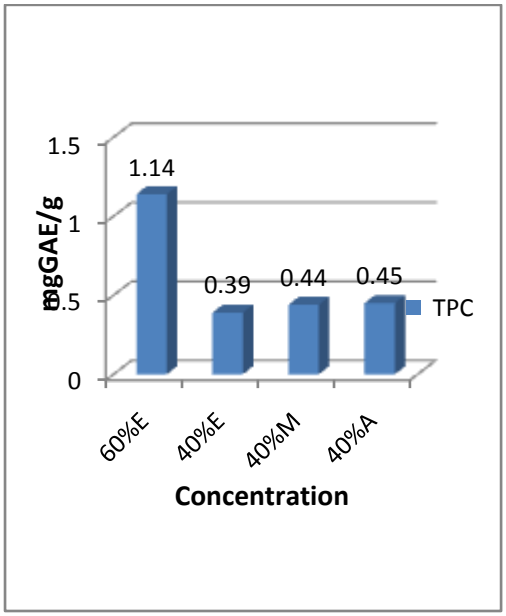
DPPH Per Cent Inhibition

Plate 4.1 Antioxidant activity of Oat

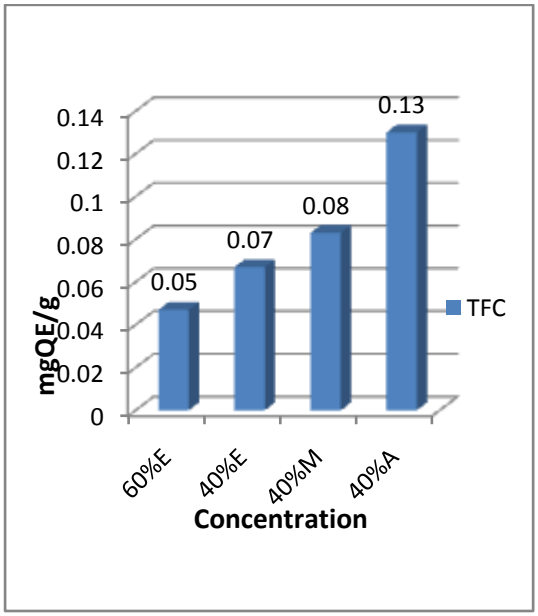
per cent ethanol and 40 per cent aceton is not significant, for DPPH the sample is treated with all the four concentrations of solvents and values were noted down at various stages of percent inhibition. 50 percent inhibition had the non significant difference with the all four solvents, 75 and 100 percent inhibition had also the similar trend and the difference between all the solvents were non significant. Singh et al. (2015) also analyzed the antioxidant properties of oat flour and he reported the total phenolic content and flavonoid content in five varieties in the range of 2687-1844 and 433-612µg/g respectively. The difference in antioxidants might be due to the solvents used because the optimal extraxction of bioactive compound with different solvent is different.

ii. **Pearl millet (*Pennisetum glaucum*)**

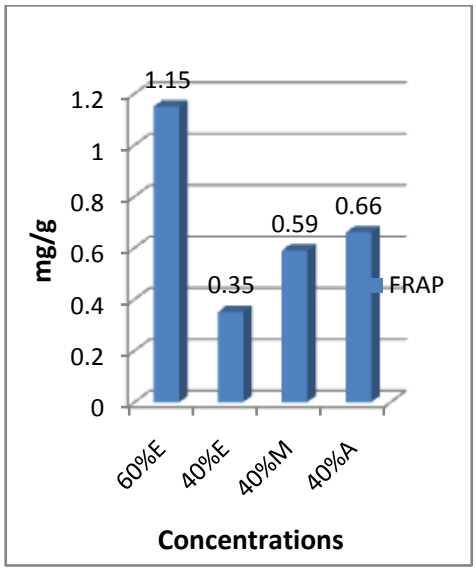
In pearl millet an attempt was made to calculate the antioxidant activity with four concentrations of three solvents i.e. 60 per cent ethanol , 40 per cent ethanol , 40 per cent methanol and 40 per cent acetone. In total phenolic content there was significant difference between values with all the solvent. In total flavonoid content and in FRAP the difference was also significant between the values with all the solvent. In DPPH at 50 per cent inhibition the difference between the solvents was non significant but the difference between 40 per cent acetone was significant with the respect to all other solvents. In 75 percent inhibition and in 100 percent inhibition the same trend was observed where overall difference was non significant but the 40 per cent acetone was significant with respect to all other solvents. Florence and Urooj (2014) studied the antioxidant in two pearl millet cultivars and reported the flavonoid content in range of 0.21-0.72 mg/g. The difference in results might be due to difference in variety or the solvents used in the extraction of bioactive compounds.



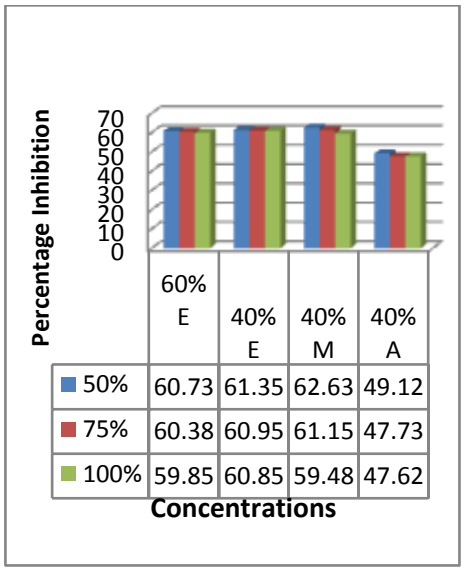
Total Phenolic Content (mgGAE/g)



Total Flavonoid Content (mgQE/g)



Ferric Reducing Antioxidant power (mg/g)



DPPH Per Cent Inhibition

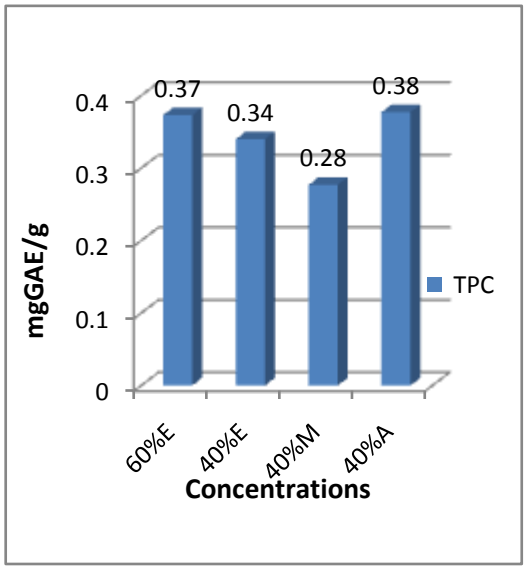
Plate 4.2 Antioxidant activity of pearl millet

iii. Sorghum (*Sorghum bicolour*)

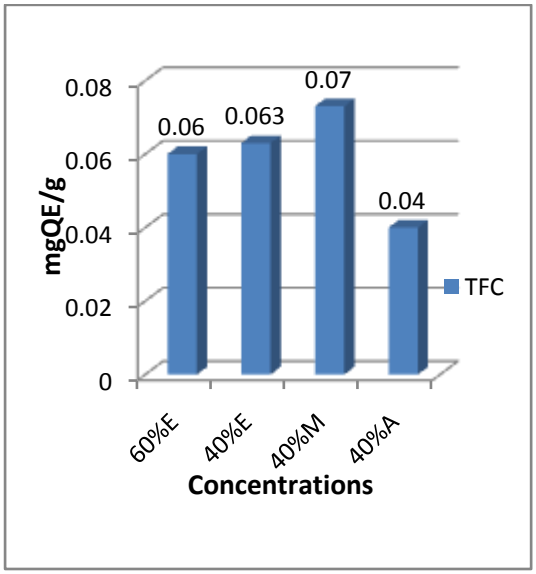
In sorghum four concentrations of three solvents i.e. 60 per cent ethanol, 40 per cent ethanol , 40 per cent methanol and 40 per cent acetone was used to evaluate the antioxidant activity of sorghum. In total phenolic content, the overall difference was significant but the difference between 60 percent ethanol and 40 percent acetone was non significant. In total flavonoid content the overall difference between all the solvents was non significant but the difference between the 40 per cent acetone with respect to all other solvents was significant. In FRAP there was significant difference between the values of all the solvents but the difference between the 40 percent ethanol and 40 per cent methanol was non significant. In DPPH 50 per cent inhibition, 75 percent inhibition and 100 per cent inhibition, there was a significant difference between all the solvents. Olosunde et al. (2015) studied the composition of sorghum – millet flour and reported the anti nutritional composition of sorghum – millet flour as phenols 0.11 per cent, oxalate 0.01per cent phytate 0.05, saponins 0.83, flavonoid 2.31, alkaloid 2.22 and tannin 1.6 mg/100 g. The slight difference in flavonoid content might be due to the polarity of the solvent used for extraction of bioactive compound.

iv. Finger millet (*Eleusine coracana L.)*

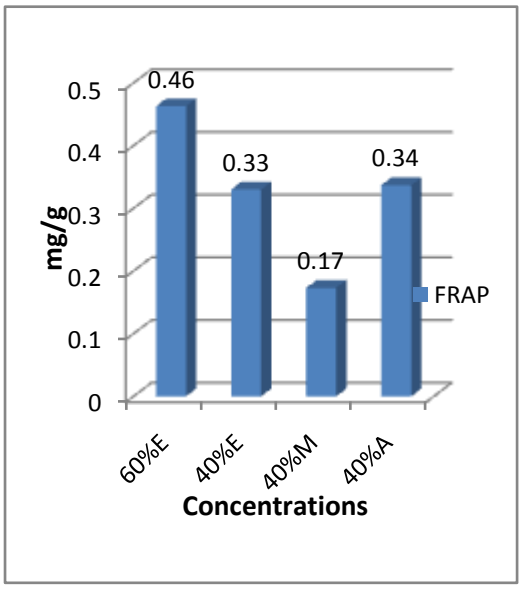
In finger millet the antioxidant activity was evaluated with four concentrations of three solvents i.e. 60 per cent ethanol, 40 per cent ethanol, 40 per cent methanol and 40 per cent acetone. It was observed that in total phenolic content, Total flavonoid and FRAP there was significant difference between the value of all the antioxidants with all the solvents. In DPPH 50 per cent inhibition there was significant difference between all the solvents and the same trend was with 75 per cent and the 100 per cent inhibition.Gull et al. (2015) studied the physiochemical, functional and antioxidant properties of millet flour and reported the total phoenolic content and DPPH in finger millet as 36.90mg/100g and 26.40 per cent respectively. Slight difference in DPPH content might be due to the concentration of solvent used in which per cent inhibition detected.



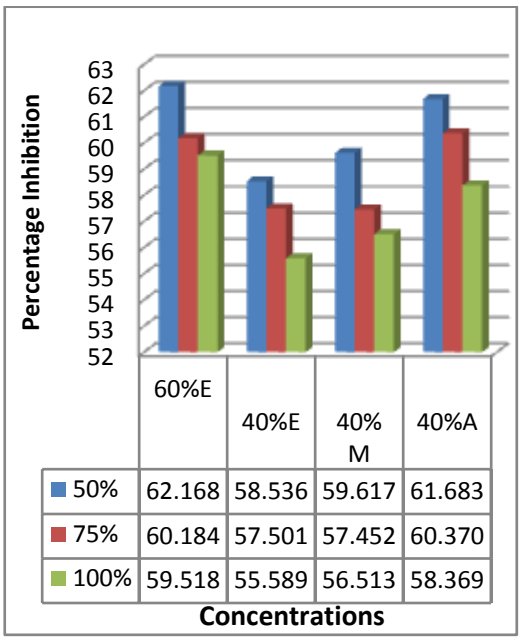
Total Phenolic Content (mgGAE/g)



Total Flavonoid Content (mgQE/g)

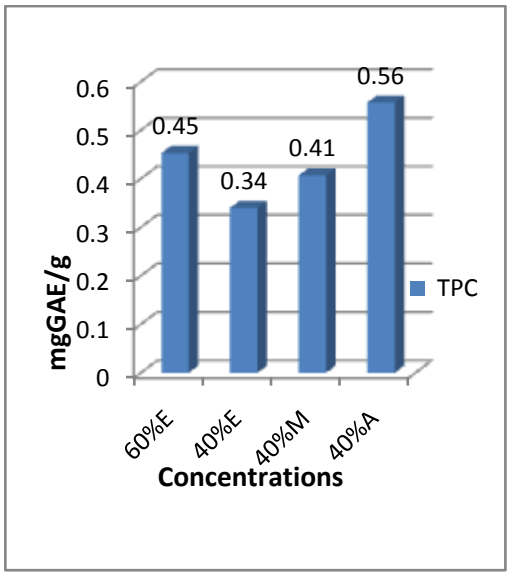


Ferric Reducing Antioxidant power (mg/g)

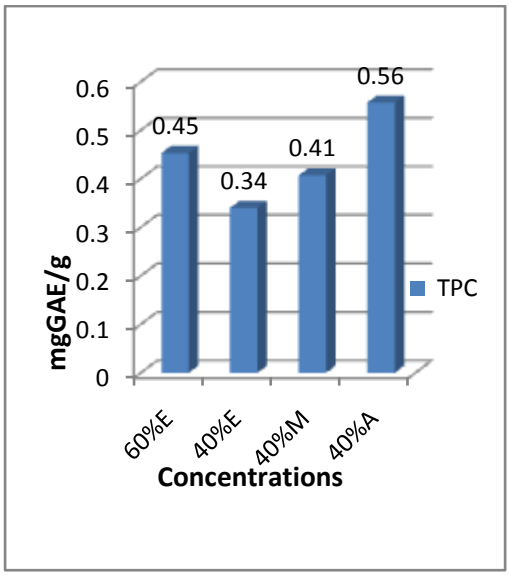


DPPH Per Cent Inhibition

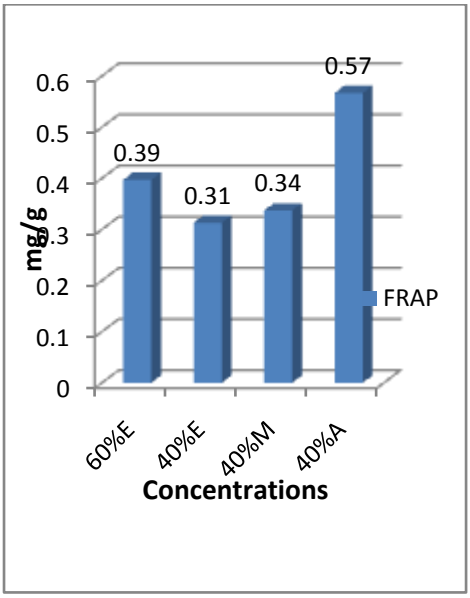
Plate 4.3 Antioxidant activity of sorghum



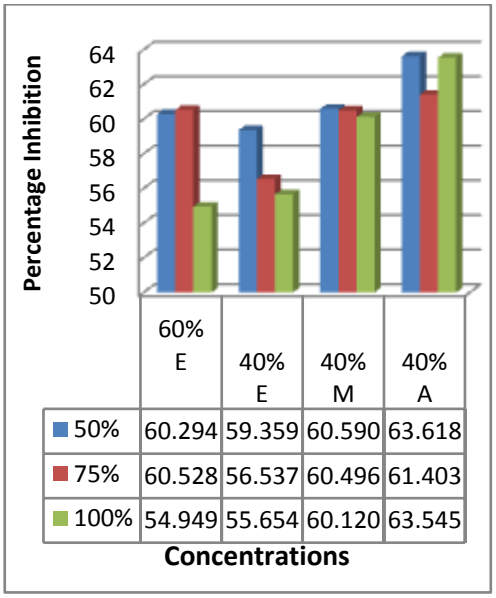
Total Phenolic Content (mgGAE/g)



Total Flavonoid Content (mgQE/g)



Ferric Reducing Antioxidant power (mg/g)



DPPH Per Cent Inhibition

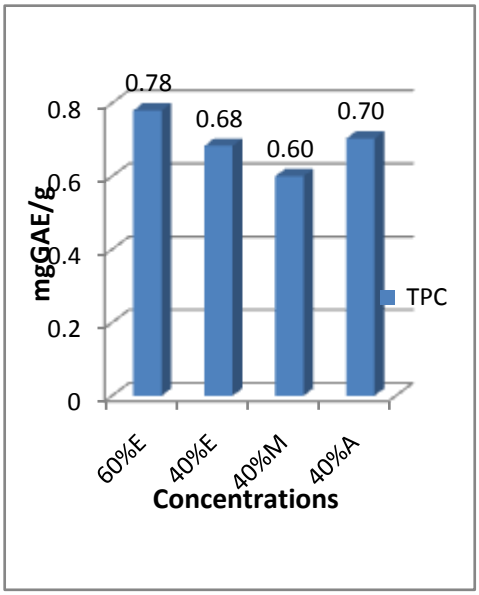
Plate 4.4 Antioxidant activity of finger millet

v. Horse gram *(Macrotyloma uniflorum)*

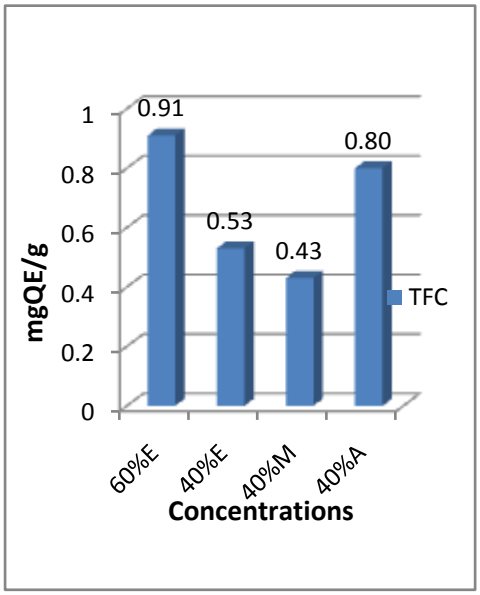
In antioxidant activity of horse gram was also evaluated with four concentrations of three solvents i.e. 60 per cent ethanol, 40 per cent ethanol, 40 per cent methanol and 40 per cent acetone. The total phenolic content, overall difference between all the solvents was significant but difference between 40 per cent ethanol and 40 per cent acetone was non significant. In FRAP the overall difference is non significant but the difference between the 40 per cent methanol with respect to all other solvent was significant. In DPPH at 50 percent inhibition the difference with all the four solvent was significant. In 75 per cent and 100 per cent inhibition the same trend was observed. Motkan and ohja (2015) studied the Quality evaluation of physical properties, antinutritional factors, and antioxidant activity of bread fortified with germinated horse gram (Dolichus uniflorus) flour and he repoterted the DPPH per cent inhibition in ungerminated horse gram flour 52.56±0.75 which is in line with the present study.

vi. Chick pea (*Cicer arietinum)*

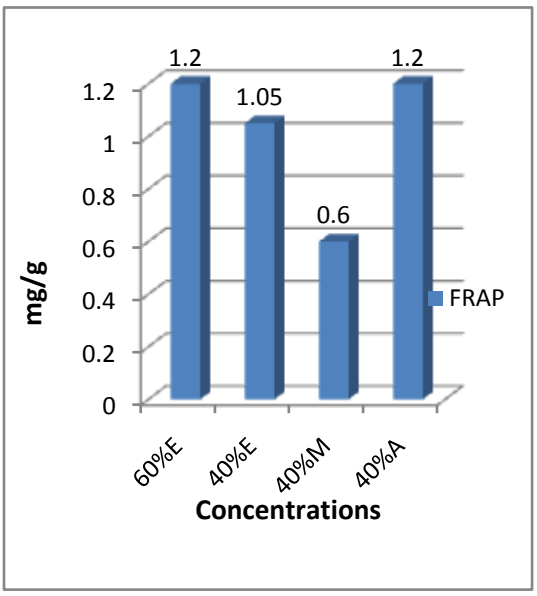
Chick pea was also treated with four concentrations of three solvents i.e. 60 per cent ethanol, 40 per cent ethanol, 40 per cent methanol and 40 per cent acetone for antioxidant activity and the total phenolic content was observed that there was a significant difference between all the solvents but the difference was non significant between the 60 per cent ethanol and 40 percent ethanol. In total flavonoid content the difference is significant with all the solvents, but the difference was non significant between 60 per cent ethanol and 40 percent ethanol. In FRAP the difference between values with all the solvents was non significant, but the difference was significant with solvent 40 per cent acetone with respect to all other solvents. In DPPH 50 per cent inhibition, the difference between 60 per cent ethanol and 40 per cent ethanol was non significant , whereas the diffrence between 40 per cent methanol & 40 percent acetone, 40 per cent methanol & 60 per cent ethanol and 40 per cent ethanol was significant. In 75 per cent inhibition difference was significant difference with all the solvents but the difference was non significant between 60 percent ethanol and 40 per cent ethanol. In 100 per cent inhibition the difference was significant with all the solvents.



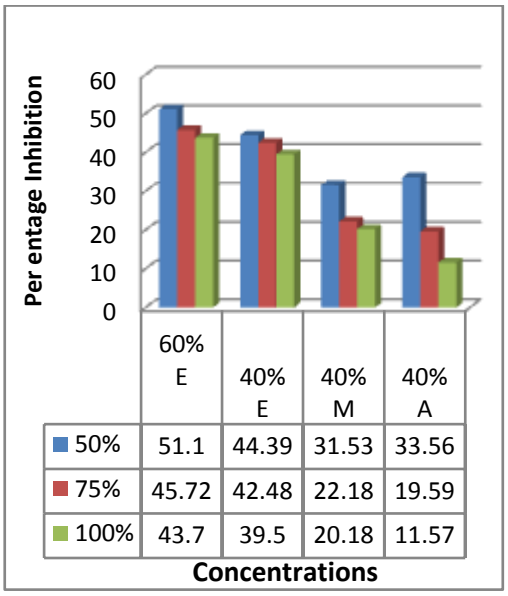
Total Phenolic Content (mgGAE/g)



Total Flavonoid Content (mgQE/g)

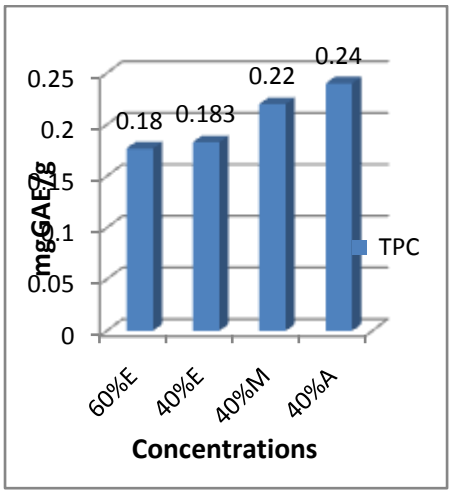


Ferric Reducing Antioxidant power (mg/g)

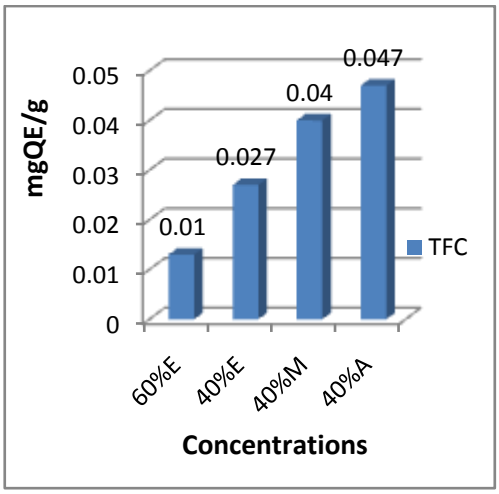


DPPH Per Cent Inhibition

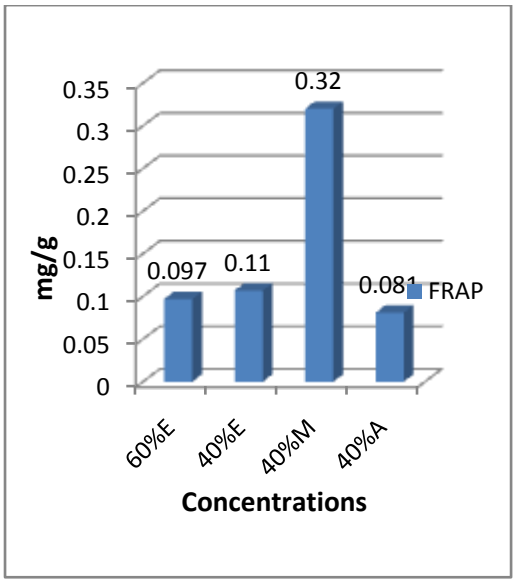
Plate 4.5 Antioxidant activity of horse gram



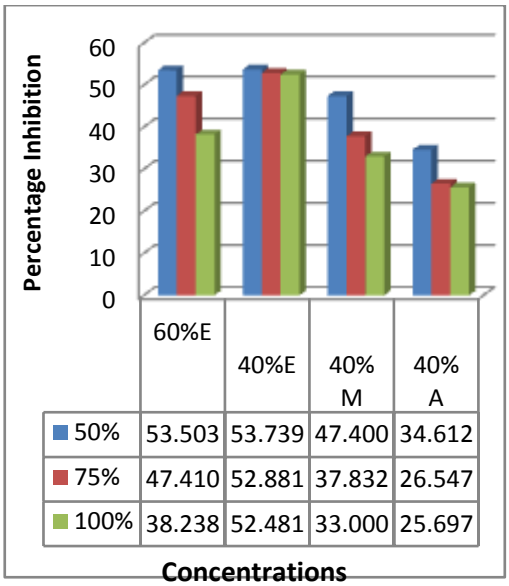
Total Phenolic Content (mgGAE/g)



Total Flavonoid Content (mgQE/g)



Ferric Reducing Antioxidant power (mg/g)



DPPH Per Cent Inhibition

Plate 4.6 Antioxidant activity of chickpea

The variations in the total phenolic contents of as extracted by using different solvent concentrations could be attributed to polarities of different compounds present in the selected cereals. The aqueous solvents had been found to be suitable for extracting some bioactive compounds with strong polarity. Acetone plus water solvent was found the best solvent for extraction of polyphenols with a broad range of polarity.

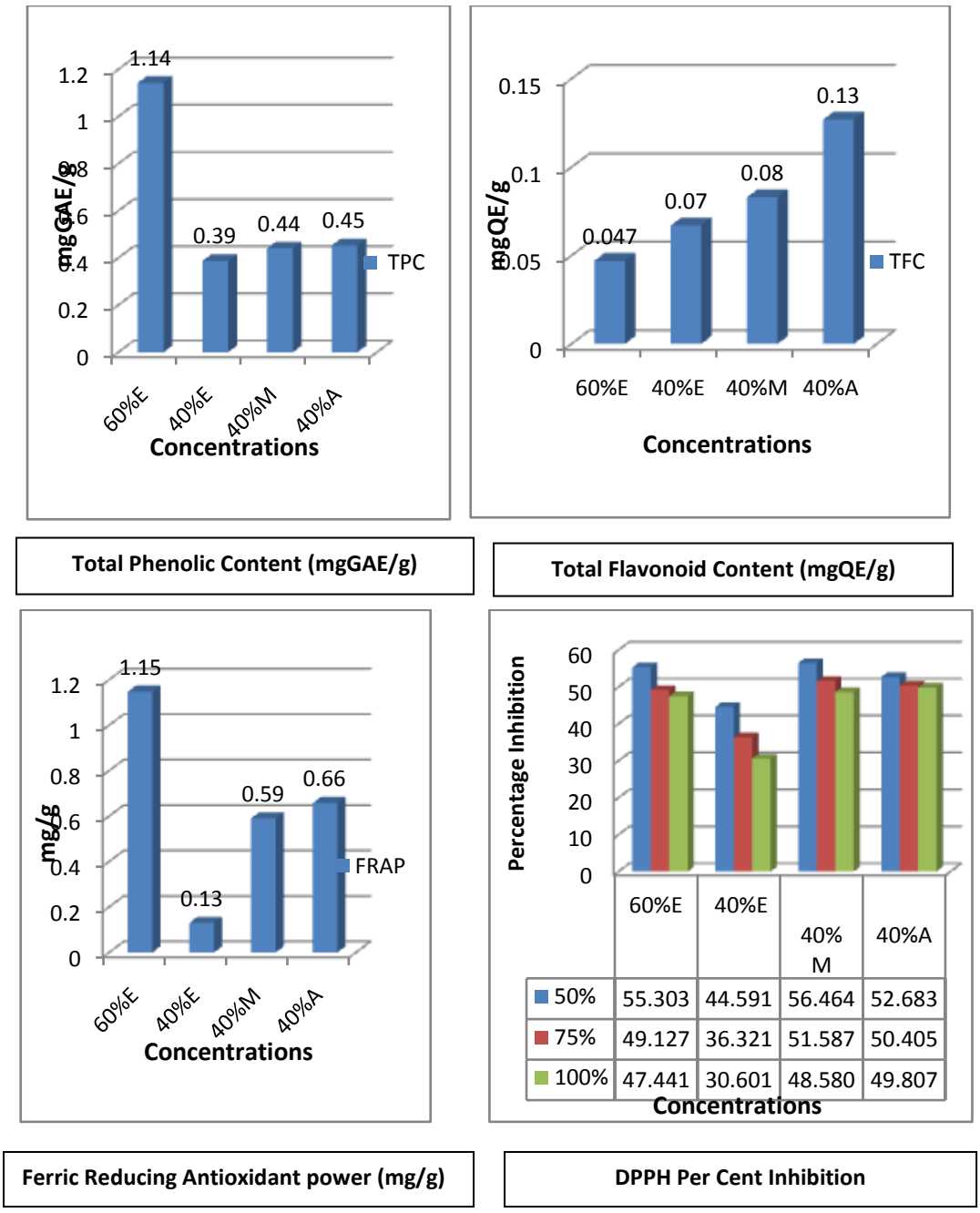


Plate 4.7 Antioxidant activity of rice bean

vii. Rice Bean (*Vigna umbellata)*

The antioxidant activity of rice bean reveals that the total phenolic and FRAP content with the significant difference between all the solvents but the 60 per cent ethanol attained the maximum value which might be due to the polarity of the solvent. In total flavonoid content the difference is significant with all the solvents, but the 40 percent ethanol showed the maximum value with rice bean which might be due to different solvents have different optimal absorption of bio active compounds. In DPPH per cent inhibition of all solvents had a significant difference.

Flavonoids have been found to possess health-promoting properties due to their higher antioxidant properties in both in-vivo and in-vitro systems and are having the ability in inducing protective enzyme systems in humans (Cook and Samman, 1996). Flavonoids have been suggested to protect the lipids against oxidative damage by various mechanisms (Kumar et al., 2013). The flavonoids have an important role in protecting large biological molecules such as proteins, lipids and DNA by scavenging free radicals that are generated during oxidative stress (Liu, 2007). Flavonoids have been reported to play an important role in regulating several biological functions by acting as antiviral, antibacterial, anti-inflammatory, antithrombotic, anti allergic and possess free radical scavenging properties (Shazia, 2013). Flavonoids include the diverse group of polyphenolic secondary metabolites and have an essential role in regulating biological functions including antiviral, antibacterial, anti-inflammatory, antithrombotic, anti allergic and possess free radical scavenging properties (Shazia, 2013). The presence 3′OH and 4′OH of the three-carbon chain in flavonoids are having the ability to donate electrons and to stop chain reactions (Cho et al., 2013).

The antioxidant capacity evaluated on the basis of DPPH activity is based on single electron transfer and thus determines the reducing capacity of antioxidant (Huang et al., 2005). The determination of antioxidant activity by DPPH radical scavenging method is considered as a better in vitro model to check the efficiency of the sample within a very short period of time. The antioxidant activity of the rice cultivars as done by DPPH method is based on the mechanism of electron transfer measures and determines the reducing capacity of antioxidants in the selected cereals.

4.2 Development of the value added products using selected test crops

The advantages of high fiber and low-protein diet are beneficial to people suffering from specific health conditions or diseases as well as to general healthy individuals. Nowadays researchers have revealed that high fiber coupled with low-protein diets may extend longevity and offer protection from several chronic diseases such as cancer, heart disease and diabetes. The major consideration for low protein diet is subjected to patients with impaired liver function, kidney disorders and for those having disorders that interfere with protein metabolism such as homocystinuria and phenylketonuria. Legumes are natural sources of high fiber plant based foods, that aids in maintain and feeding the diverse colony of healthy bacteria in the gut. The high-fiber cereals offers several benefits like keeping the gut healthy, boosting heart health, and promoting weight loss. The healthy gut micro biomes are associated with lower rates of obesity and type 2 diabetes.

Keeping into consideration all of the benefits associated with high fibre and low protein intake, the selected crops of cereals and pulses *viz.* oat grains, finger millet, pearl millet sorghum, horse gram, chick pea and rice bean were selected.

4.2.1 Prepartion of bread

i. Experimental design

Response surface methodology (RSM) was used to design the experiment. The high and low levels of five independent variables were chosen. In table 4.18. Each variable was tested by performing the preliminary trials and literature. The Box Behken design for the five independent variables at five levels each was performed for proximate composition. Product responses including moisture (%), fat (%), ash (%), protein (%) and fiber (%) were studied. RSM was used to optimize the level of cereals for quality bread product. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

Table 4. 17 Experimental design for bread preparation

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Response 1	Response 2	Response 3	Response 4	Response 5
Run	A	B	C	D	E	Moisture	Ash	Fat	protein	Fiber
	G	G	G	g	G	%	%	%	%	%
1	0	-1	1	0	0	28.75	4	5.83	3.51	0.29
2	0	0	0	0	0	27	4	5.68	3.51	0.24
3	0	0	1	0	-1	26	4.29	5.3	3.42	0.29
4	1	0	0	-1	0	25.61	4.06	5.25	3.38	0.21
5	-1	0	1	0	0	29	4	5.68	3.51	0.29
6	-1	0	0	1	0	26.77	3.84	5.16	3.39	0.22
7	-1	0	0	0	1	28.34	3.76	5.09	3.28	0.26
8	0	1	0	0	-1	26	3.93	5.14	3.26	0.29
9	1	0	0	0	1	29	4	5.39	3.95	0.29
10	0	1	0	1	0	24.59	4	5.34	3.51	0.24
11	0	0	0	0	0	26	3.98	5.3	3.42	0.29
12	1	0	0	0	-1	27.31	4.06	5.25	3.38	0.23
13	1	0	-1	0	0	29	4	5.68	3.51	0.29
14	0	0	0	0	0	25.03	3.84	5.16	3.39	0.2
15	0	0	1	0	1	28.34	3.76	5.09	4.28	0.25
16	0	1	0	-1	0	26	4	5.68	3.51	0.26
17	0	0	0	1	-1	27.31	4.12	5.3	4	0.29
18	0	-1	0	0	-1	29	4.06	5.25	4.38	0.29
19	0	0	1	-1	0	25.03	4	5.68	3.96	0.22
20	0	0	-1	0	1	28.34	3.99	5.16	3.39	0.29
21	1	0	0	1	0	26	3.76	5.09	4.28	0.29

22	0	0	-1	0	-1	29	3.93	5.14	3.26	0.21
23	-1	1	0	0	0	25.03	4	5.4	3.51	0.29
24	-1	-1	0	0	0	27.55	4	5.68	4.51	0.29
25	-1	0	-1	0	0	26.43	3.99	5.3	3.42	0.25
26	0	-1	0	-1	0	26.48	4.06	5.63	3.38	0.22
27	0	-1	-1	0	0	25.03	4	5.33	4.02	0.26
28	0	0	-1	1	0	27.31	3.84	5.16	3.39	0.22
29	0	1	-1	0	0	26.73	3.91	5.56	3.28	0.25
30	0	0	0	0	0	29	3.93	5.14	4.26	0.22
31	0	1	0	0	1	25.03	4.06	5.25	3.51	0.25
32	-1	0	0	-1	0	28.34	4	5.68	3.92	0.29
33	0	1	1	0	0	26	3.95	5.16	3.91	0.29
34	0	0	0	0	0	27.31	3.76	5.09	3.26	0.26
35	-1	0	0	0	-1	29	4.11	5.14	3.96	0.29
36	1	1	0	0	0	25.03	4	5.68	3.51	0.26
37	0	0	1	1	0	28.34	3.84	5.16	3.96	0.29
38	0	0	0	1	1	26	3.74	5.14	3.26	0.26
39	0	-1	0	1	0	29	3.76	5.36	4.28	0.29
40	1	-1	0	0	0	27	3.84	5.45	3.39	0.29
41	0	0	-1	-1	0	26.55	3.84	5.16	3.39	0.29
42	0	0	0	0	0	27.31	4.06	5.25	3.51	0.29
43	1	0	1	0	0	25.03	3.84	5.16	4.39	0.23
44	0	-1	0	0	1	29	3.76	5.68	3.42	0.27
45	0	0	0	-1	-1	25.03	3.93	5.3	3.38	0.23
46	0	0	0	-1	1	28.34	4	5.25	3.96	0.23

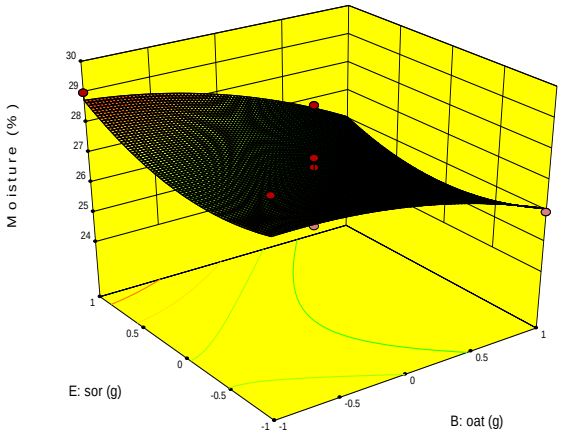
Table 4.18 Data analysis of bread preparation

Parameters	Moisture	Fat	Ash	Protein	Fiber
β_0	+26.94	+5.27	+3.93	+3.56	+0.25
Wheat-A	-0.41	-0.01	-8.75	+0.02	-5.62
Oat-B	-1.09	-0.06	+0.02	-0.18	-4.37
Pearl millet-C	-0.12	+0.04	+0.01	+0.21	+5.62
Finger millet-D	+0.25	-0.12	-0.06	+0.07	+9.37
Sorghum-E	+0.23	+0.01	-0.08	+6.25	-1.25
A^2	+0.20	+0.08	+0.01	+0.10	+0.01
B^2	-0.49	+0.19	+0.02	+0.07	+0.02
C^2	+0.23	+0.03	+8.54	+0.04	+6.25
D^2	-0.45	+0.02	-0.02	+0.07	-7.08
E^2	+0.75	-0.11	+0.03	+1.04	+7.08
AB	+0.14	+0.13	+0.04	+0.28	-7.50
AC	-1.63	-0.22	-0.04	+0.20	-0.02
AD	+0.49	+0.09	-0.03	+0.36	+0.04
AE	+0.59	+0.05	+0.07	+0.31	+0.02
BC	-1.11	-0.22	+0.01	+0.28	+2.50
BD	-0.98	-0.02	+0.07	-0.23	-0.02
BE	-0.24	-0.08	+0.11	+0.30	-5.00
CD	+0.64	-0.13	-0.04	+5.00	+0.03
CE	+0.75	-0.06	-0.15	+0.18	-0.03
DE	-1.15	-0.03	-0.11	-0.33	-7.50
R-Squared	0.69	0.69	0.74	0.68	0.71
Lack of fit (F-value)	0.84	0.89	0.93	0.86	0.99
Adequate precision	6.99	6.95	9.81	6.22	6.99

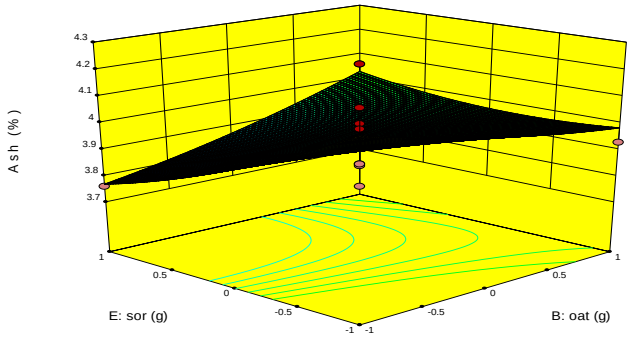
ii. Data analysis of bread

The result for estimated coefficient of the fitted Second order polynomial are presented in table 4.58 .The fitted model had the coefficient of determination (R^2) for various responses as 0.69 for moisture and fat, 0.74 for ash, 0.68 for protein and 0.71 for fiber. The lack of fit value and adequate precision for all the responses (moisture , fat , ash , protein and fiber) are as 0.84, 0.89, 0.93, 0.86 and 6.99, 6.95, 9.81, 6.22, 6.99 respectively. The regression analysis reveals that independent variable A(Wheat) , B(Oat) and C (Pearl millet) had a significant ($p \leq 0.001$) negative linear effect on moisture content while as the variable D (Finger millet) and E (Sorghum) had a significant ($p \leq 0.001$) positive linear effect on moisture content. A significant ($p \leq 0.05$) positive quadratic effect was depicted by variable A, C and E and a significant ($p \leq 0.05$) negative quadratic effect was shown by B and D on moisture content. However the significant ($p \leq 0.05$) positive effect was depicted by the interaction of variable CE and CD while as the combination of variable AC and DE had significant

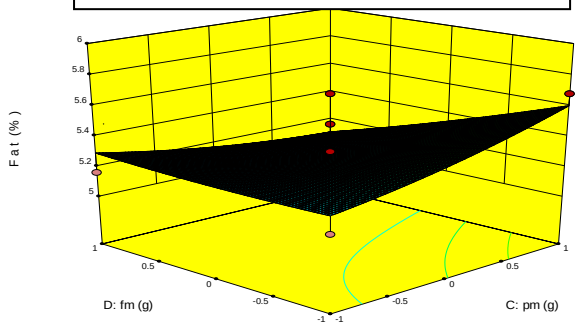
($p \leq 0.05$) negative effect on moisture content with the constant value (B_0) as 26.94. The regression analysis of response for fat showed a constant value (B_0) of 5.27 depicting a significant negative linear effect with A, B and D, however the effect was not prominent. The variable C and D showed a significant ($p \leq 0.001$) positive linear effect on fat content, while as the combination of AC and BC indicated negative correlation. The experimental design was found to display a constant value (B_0) of 3.93 for ash content depicting positive correlation with variables C and negative linear effect ($p \leq 0.001$) with A. However in terms of significant ($p \leq 0.05$) positive effect with combination of variables, the BE was found to be significant where as DE showed significant ($p \leq 0.05$) negative effect on ash content. The regression analysis of protein and fiber showed a constant value of 3.56 and 0.25. In response protein all the variables had a significant ($p \leq 0.001$) positive linear effect but variable B had a significant ($p \leq 0.001$) negative linear effect. The quadratic coefficient of all the variable had significant ($p \leq 0.05$) positive quadratic effect. However in terms of interaction significant ($p \leq 0.05$) positive effect of the variables CD and significant ($p \leq 0.05$) negative effect with variables DE on protein content. The regression analysis of response fiber showed a significant ($p \leq 0.001$) negative linear effect with variable A and B where as variable C and D had a significant ($p \leq 0.001$) positive linear effect. The quadratic coefficient of variable D had a significant ($p \leq 0.05$) negative quadratic effect. In interaction of variables BE and DE had a very significant ($p \leq 0.05$) negative effect and BC had a very significant ($p \leq 0.05$) positive effect on response fiber. The response surface plot as shown in Figure (4.1)



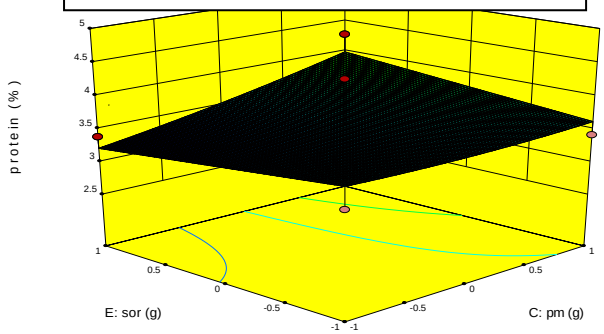
1. B (oat) : E (sorghum)



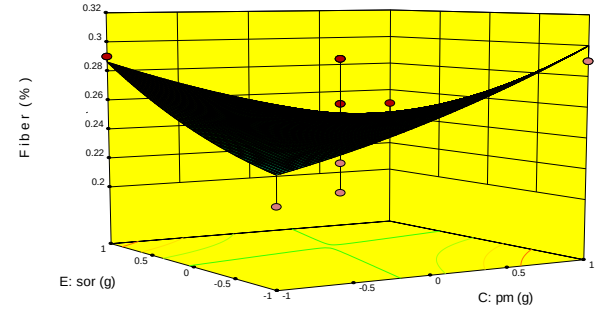
2. B (oat) : E (sorghum)



3. C (pearl millet) : D (finger millet)



4. C (pearl millet) : E (Sorghum)



5. C (pearl millet) : E (Sorghum)

Figure 4.1: Response surface plots for bread

iii. Figure 4.1shows the surface plots of moisture, ash, fat, protein and fiber. There is increase in the moisture content with the increase in the sorghum as compare to oat. Plot. 2 explain the effect of the variable B and E on ash content as it is clear from the graph that ash content increases with the increase of the oat flour as compare to the sorghum. In case of fat (Plot.3) there is increase in fat content with the increase of pearl millet and finger millet, but the increase is not significant with finger millet. The protein content (Plot.4) increase with the increase of pearl millet and sorghum, but the increase is not significant in case of sorghum. The plot for response fiber (Plot.5) shows that there is increase in fiber content with the increase of pearl millet and sorghum, but the significant effect with pearl millet.

iv. Experimental design

Box Behkhen design was carried out for five independent variables of cereals. The high and low levels of five independent variables were chosen as discussed in table 4.19. Each variable was tested by performing the preliminary trials and literature. The Box Behken design for the five independent variables at four levels each was performed for starch composition. Product responses including amylose, starch, resistant starch and Glycemic index were studied. RSM was used to optimize the level of cereals for quality bread product. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

Table 4.19 Experimental design for bread preparation

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Response 1	Response 2	Response 3	Response 4
Run	A:oat grains	B:P.M	C:F.M	D:Sor.	E:Wheat	Amylose	Starch	R.Starch	G.I
	G	g	G	G	g	%	%	%	
1	-1	0	-1	0	0	11.21	35.6	4.27	51
2	1	0	0	-1	0	11.13	35.62	4.33	51
3	0	0	0	0	0	11.23	35.6	4.28	51
4	1	-1	0	0	0	11.16	35.48	4.27	50
5	0	0	-1	0	-1	11.16	35.6	4.26	51
6	1	0	0	1	0	11.18	35.6	4.28	51
7	0	0	1	0	1	11.15	35.59	4.26	51
8	0	0	1	-1	0	11.17	35.7	4.27	51.04
9	0	-1	0	1	0	11.24	35.7	4.25	51
10	0	1	0	-1	0	11.22	35.67	4.3	51
11	0	0	-1	-1	0	11.23	35.6	4.31	51
12	1	0	0	0	-1	11.17	35.57	4.31	51
13	0	-1	0	-1	0	11.17	35.63	4.3	50.83
14	0	0	0	0	0	11.14	35.61	4.32	51
15	1	0	-1	0	0	11.12	35.62	4.31	51
16	0	1	-1	0	0	11.22	35.65	4.29	51
17	0	-1	-1	0	0	11.21	35.61	4.27	51
18	0	0	0	-1	1	11.19	35.63	4.28	50
19	0	0	1	1	0	11.21	35.67	4.28	51
20	-1	0	0	0	-1	11.18	35.67	4.25	51
21	1	1	0	0	0	11.25	35.67	4.31	51
22	1	0	1	0	0	11.17	35.62	4.3	50
23	-1	-1	0	0	0	11.23	35.65	4.28	51
24	-1	0	0	0	1	11.2	35.49	4.28	51
25	0	0	-1	0	1	11.16	35.61	4.3	51
26	-1	1	0	0	0	11.18	35.51	4.28	51
27	0	-1	0	0	-1	11.15	35.52	4.26	51.33
28	0	0	0	0	0	11.21	35.7	4.27	51

29	-1	0	0	-1	0	11.24	35.63	4.25	51
30	0	0	0	1	1	11.18	35.62	4.33	51.54
31	0	0	0	0	0	11.23	35.64	4.31	51
32	0	1	0	0	1	11.21	35.57	4.3	52
33	0	-1	0	0	1	11.17	35.63	4.29	50.46
34	1	0	0	0	1	11.14	35.61	4.32	51
35	-1	0	0	1	0	11.16	35.62	4.29	51
36	0	1	0	0	-1	11.22	35.71	4.29	51
37	0	1	0	1	0	11.21	35.68	4.27	51.33
38	-1	0	1	0	0	11.19	35.63	4.28	51
39	0	1	1	0	0	11.21	35.67	4.26	51
40	0	0	-1	1	0	11.18	35.67	4.25	51
41	0	0	0	1	-1	11.22	35.67	4.25	50
42	0	-1	1	0	0	11.23	35.64	4.31	51
43	0	0	0	0	0	11.21	35.65	4.35	51
44	0	0	0	-1	-1	11.17	35.63	4.33	51
45	0	0	0	0	0	11.14	35.61	4.32	52
46	0	0	1	0	-1	11.16	35.68	4.31	50.54

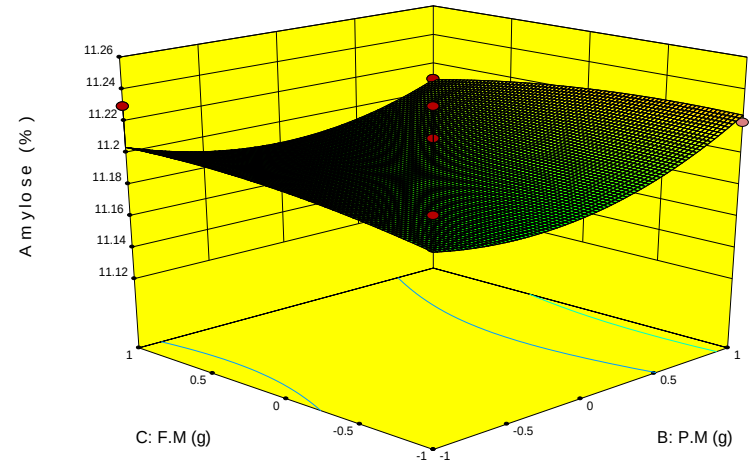
Table 4.20 Data analysis of bread preparation

Parameters	Amylose	Starch	Resistant Starch	Glycemic Index
β_0	+11.19	+35.64	+4.31	+51.17
Oat-A	-0.02	-6.25	+0.02	-0.13
Pearl millet-B	+1.00	+0.02	+4.37	+0.17
Finger millet-C	+1.16	+0.01	+6.25	-0.09
Sorghum-D	+3.75	+7.50	-0.01	+0.06
wheat-E	-1.87	-0.02	+6.25	+0.07
A^2	-0.01	-0.04	-8.12	-0.19
B^2	+0.02	-4.58	-0.01	-0.03
C^2	-5.62	+9.58	-0.01	-0.14
D^2	+4.37	+0.02	-0.01	-0.13
E^2	-0.02	-0.02	-7.29	-0.12
AB	+0.03	+0.08	+0.01	+0.25
AC	+0.02	-7.50	-5.00	-0.25
AD	+0.03	-2.50	-0.02	-1.48
AE	-0.01	+0.05	-5.00	+7.59
BC	-7.50	-2.50	-0.02	+5.24
BD	-0.02	-0.01	+5.00	+0.04
BE	-7.50	-0.06	-5.00	+0.47
CD	+0.02	-0.02	+0.02	-1.00
CE	-2.50	-0.02	-0.02	+0.12
DE	-0.015	-0.01	+0.03	+0.63
R-Squared	0.65	0.87	0.74	0.64
Lack of fit (F-value)	*0.99*	*0.97*	*0.99*	*0.88*
Adequate precision	6.25	12.64	8.22	6.83

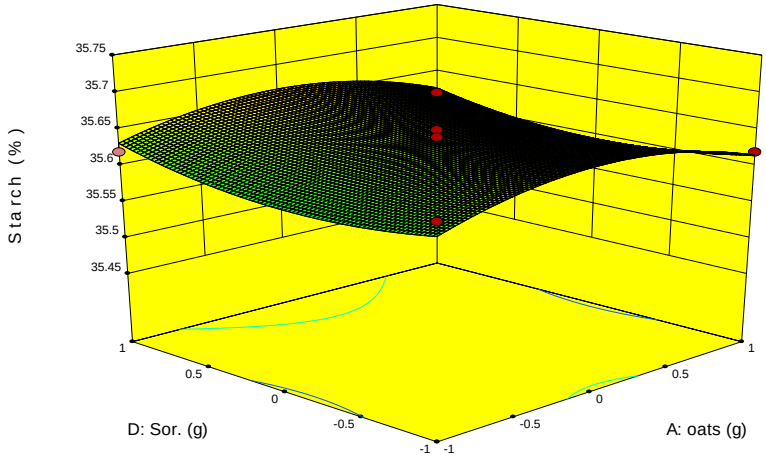
v. Data analysis of bread

The results for estimated coefficient of starch are presented in Table 4.20. The fitted model had the coefficient of determination (R^2) for various responses as amylose (0.65), starch (0.87) resistant starch (0.74) and glycemic index (0.64). The adequate precision values were found as 6.25, 12.64, 8.22, 6.83 while as the lack of fit values were 0.99, 0.97, 0.99 and 0.88 for amylose, starch, resistant starch and glycemic index respectively. The constant values (b_0) are 11.19 for amylose content, 35.64 for starch, 4.31 for resistant starch and 51.17 for glycemic index. Variable B, C and D showed a significant ($p \leq 0.001$) positive linear effect on response amylose content where as variable E displayed a significant ($p \leq 0.001$) negative linear effect. The quadratic coefficient of variable C showed a significant ($p \leq 0.05$) negative quadratic effect as compare to quadratic coefficient of variable D that depicted positive correlation. In interaction of variables, BC and BE had a very significant

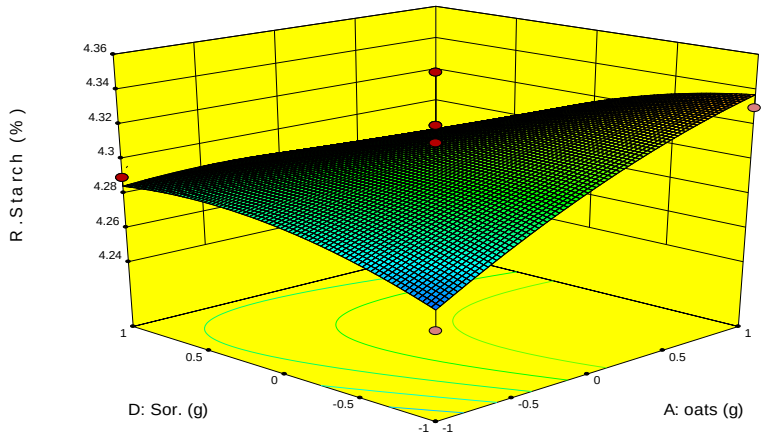
($p \leq 0.05$) negative effect on amylose content. In case of starch variable A had very significant ($p \leq 0.001$) negative linear while D had Very significant ($p \leq 0.001$) positive linear effect. The quadratic coefficient of variable B showed very significant ($p \leq 0.05$) negative quadratic effect whereas C had a very positive effect on starch content. In interaction of variables, AC, AD and BC had significant ($p \leq 0.05$) negative effect on starch. In case of resistant starch variable B, C and E had a very significant ($p \leq 0.001$) positive linear effect while A and E showed very significant ($p \leq 0.05$) negative quadratic effect. The interaction of variable AC, AE and BE had a significant ($p \leq 0.05$) negative effect while BD displayed significant ($p \leq 0.05$) positive effect. The response surface plot as shown in Figure (4.2).



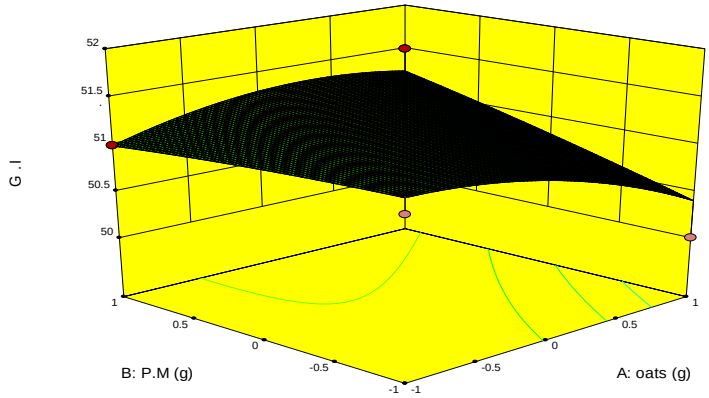
1. B (Pearl millet) : C (Finger millet)



2. A(Oat) : D (Sorghum)



3. A (Oat) : D (Sorghum)



4. B (Pearl millet) : A (Oat)

Figure 4.2: Response surface plots for Bread

vi. Figure 4.2 depicts the effect of variables on bread response amylose, starch, resistant starch and glycemic index respectively. From Plot.1 it is clear that there is increase in amylose content with pearl millet and finger millet, but the increase is more in case of pearl millet. In case of Plot.2 depicts that there is increase in starch content with oat and sorghum, but the increase is significant with sorghum. In figure 4.2 Plot.3 reveals that resistant starch increased significantly with oat as compare to the sorghum. In case of glycemic index (Plot.4) oat was found to indicate a increasing trend as compare to pearl millet.

4.2.2 Preparation of soup sticks

i. Experimental design for soup stick preparation

Response surface methodology (RSM) was used to design the experiment. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.Central Box Behken design was done for four independent variables of cereals and pulses as shown in Table 4.21. The high and low levels of four independent variables were chosen as discussed in Table. Each variable was tested by performing the preliminary trials and literature. The Box Behken design for the four independent variables at five levels each was performed for proximate composition. Product responses including Moisture (%), Ash (%), Fat (%), Protein (%) and Fiber (%) were studied. RSM was used to optimize the level of cereals and pulses for quality soup stick product, the optimized products were then assessed for storage studies of 120 days.

ii. Data analysis of soup stick

The results for estimated coefficient for chemical analysis are reported in table 4.64. The fitted model showed the constant values for responses moisture (4.00), Ash (5.36), Fat (0.70), fiber (0.38) and protein (6.33). All the variables and quadratic coefficients of variables showed a significant ($p \leq 0.001$) positive linear effect while as variable B had significant ($p \leq 0.05$) negative quadratic effect on moisture content. However in Interaction of variables, AD and AC had significant ($p \leq 0.05$) positive effect and variable BC, CD depicted significant ($p \leq 0.05$) negative effect with moisture content. Coefficient of determination was observed as 0.79, Lack of fit as 0.98 and adequate precision as 8.48 for response moisture. The regression analysis for response ash showed a significant ($p \leq 0.001$) positive linear effect for the entire variable but the quadratic coefficient of variable A had a significant ($p \leq 0.05$) negative quadratic effect. All interactions depicted a negative effect on ash except

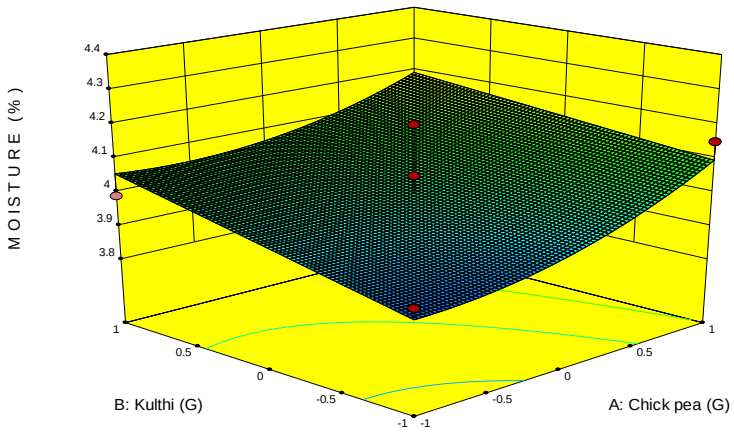
Table 4.21 Experimental design for soup sticks

	Factor 1	Factor 2	Factor 3	Factor 4	Response 1	Response 2	Response 3	Response 4	Response 5
Run	A:Chick pea	B:Kulthi	C:Rice bean	D:wheat	MOISTURE	ASH	FAT	FIBER	PROTEIN
	G	G	G	G	%	%	%	%	%
1	0	-1	0	1	4.1	5.64	0.44	0.45	6.1
2	0	0	0	0	4.2	5.34	0.87	0.35	6.9
3	0	0	0	0	4.05	5.15	0.45	0.22	6.46
4	-1	0	-1	0	4	5	0.67	0.56	7
5	0	0	0	0	3.88	5.67	0.64	0.21	5.9
6	-1	0	1	0	4	5.5	0.65	0.59	5.89
7	1	0	-1	0	4.1	5.62	0.36	0.65	6.25
8	0	1	0	1	4.34	5.57	0.65	0.59	6.33
9	0	0	-1	1	4.3	5.24	0.56	0.47	6.05
10	0	0	-1	-1	3.98	5.56	0.46	0.5	6.7
11	0	0	1	-1	4.13	5.27	0.65	0.15	5.78
12	0	1	-1	0	4.12	5	0.33	0.65	6.65
13	1	1	0	0	4.15	5.6	0.55	0.34	6.54
14	0	1	0	-1	4.1	5.87	0.67	0.43	6.35
15	-1	0	0	1	4.05	5.45	0.49	0.56	6.2
16	0	0	0	0	3.95	5.23	0.76	0.47	6.24
17	-1	1	0	0	3.99	5.54	0.75	0.9	6.34
18	1	0	0	-1	4.15	5.78	0.65	0.25	5.98
19	0	1	1	0	4.1	6	0.76	0.24	6
20	0	-1	0	-1	4	5.58	0.45	0.52	6.8
21	0	-1	-1	0	3.81	5.76	0.45	0.26	6.7
22	1	0	1	0	4.26	5.27	0.7	0.22	6
23	-1	0	0	-1	4.11	5.1	0.76	0.51	6.72
24	1	0	0	1	4.33	5.65	0.76	0.47	6.55
25	1	-1	0	0	4.15	5.75	0.74	0.57	5.98
26	0	0	1	1	4.1	5.98	0.45	0.54	6.37
27	-1	-1	0	0	3.9	5.1	0.53	0.5	7
28	0	0	0	0	3.92	5.43	0.76	0.66	6.15
29	0	-1	1	0	3.99	5.45	0.34	0.58	6.66

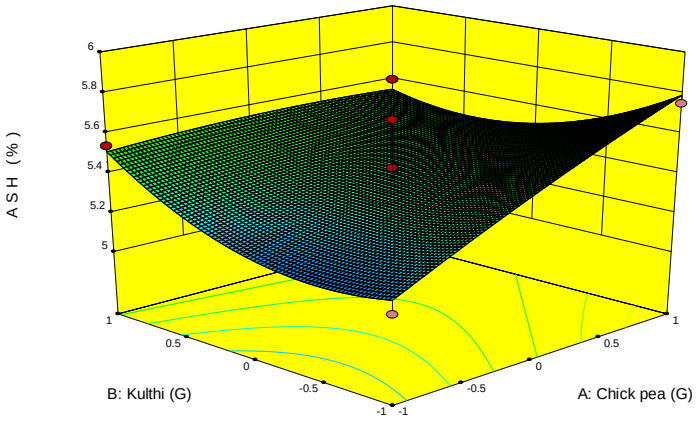
Table 4.22 Data analysis of soup stick

Parameters	Moisture	Ash	Fat	Fiber	Protein
β_0	+4.00	+5.36	+0.70	+0.38	+6.33
Chick pea-A	+0.09	+0.17	-7.50	-0.09	-0.15
Horse gram-B	+0.07	+0.025	+0.06	+0.02	-0.086
Rice bean-C	+0.02	+0.11	+0.06	-0.06	-0.22
wheat -D	+0.06	+0.031	-0.02	+0.06	-0.061
A^2	+0.05	-0.024	+0.03	+0.09	+0.019
B^2	-4.17	+0.16	-0.09	+0.08	+0.14
C^2	+0.017	+0.013	-0.13	+6.08	-0.031
D^2	+0.12	+0.14	-0.05	+9.83	-0.046
AB	-0.023	-0.15	-0.10	-0.16	+0.31
AC	+0.040	-0.21	+0.09	-0.12	+0.22
AD	+0.060	-0.12	+0.09	+0.04	+0.27
BC	-0.050	+0.33	+0.13	-0.18	-0.15
BD	+0.035	-0.090	-2.50	+0.06	+0.17
CD	-0.088	+0.26	-0.07	+0.11	+0.31
R-Squared	0.7930	0.8510	0.7474	0.7724	0.7543
Lack of fit (F-value)	*0.9803*	*0.8953*	*0.9756*	*0.9950*	*0.9805*
Adequate precision	8.483	10.393	6.077	7.934	7.045

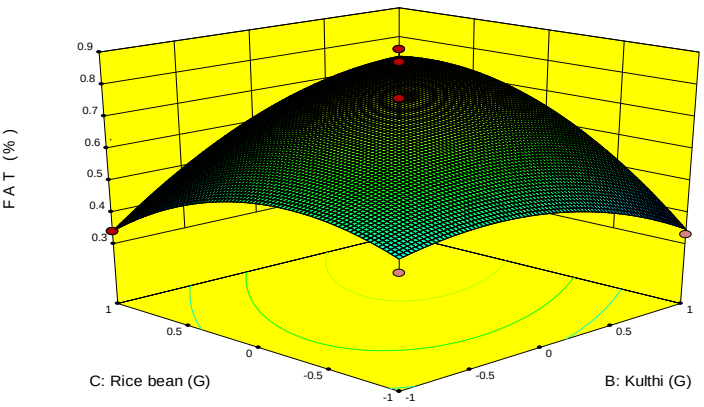
variable BC and CD. The regression analysis of fat, showed a significant ($p \leq 0.001$) negative linear effect with variable A. The quadratic coefficient of variable A showed significant ($p \leq 0.05$) positive quadratic effect while all other variable had significant ($p \leq 0.05$) negative quadratic effect. In interaction of variables, BD had a significant ($p \leq 0.05$) negative effect where as variables BC had a significant ($p \leq 0.05$) positive effect. In response fiber variable AC had significant ($p \leq 0.05$) negative and BD had significant ($p \leq 0.05$) positive effect and the quadratic coefficient of variable C and D had a significant significant ($p \leq 0.05$) positive quadratic effect. In interaction variable BC had significant ($p \leq 0.05$) negative effect but CD had significant ($p \leq 0.05$) positive effect. In response to protein all the variables had a significant ($p \leq 0.001$) negative linear effect but the quadratic coefficient of variables A and B had significant ($p \leq 0.05$) positive quadratic effect. The interaction of variables AB and CD had a significant ($p \leq 0.05$) positive effect but the BC had the significant ($p \leq 0.05$) negative effect on protein content. The response surface plot as shown in Figure (4.3)



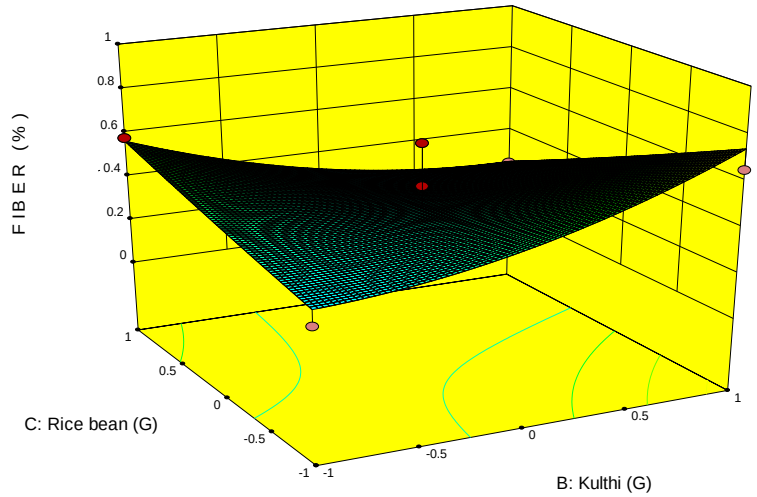
1. B (Kulthi) : A (Chick pea)



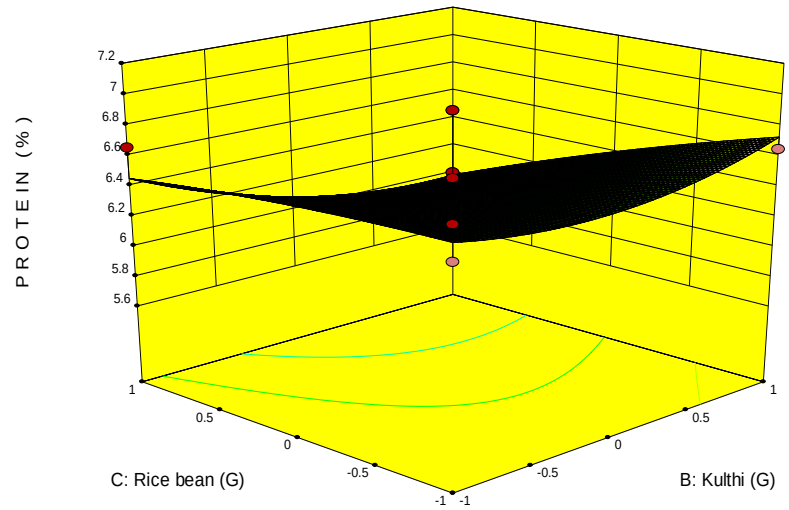
2. B (Kulthi) : A (Chick pea)



3. B (Kulthi) : C (Rice bean)



4. B (Kulthi) : C (Rice bean)



5. B (Kulthi) : C (Rice bean)

Figure 4.3: Response surface plots for soup sticks

iii. Figure 4.3 shows the surface plots for moisture, ash, fat, fiber and protein respectively. Plot.1 depicts that effect of chick pea and kulthi on moisture, there is increase in moisture content with the increase of chick pea and kulthi but the increase is significant with chick pea. In response ash (Plot.2) there is increasing effect with increase of chick pea and kulthi but the effect is significant with chick pea. Plot.3 depicts the effect of rice bean and kulthi on fat content, there is increase in fat content with the increase of both the variables (rice bean and kulthi) but the effect is non significant. In case of fiber (Plot.4) and protein (Plot.5) variable B (Kulthi) and C (Rice bean) has increasing effect but the variable B shows significant effect.

iv. Experimental design for soup stick

Response surface methodology (RSM) was used to design the experiment. Box Behken design was done for four independent variables of cereals and pulses as shown in Table 4.23 . The high and low levels of four independent variables were chosen as discussed in Table. Each variable was tested by performing the preliminary trials and literature. The Box Behken design for the four independent variables at four levels each was performed for starch composition. Product responses including Starch, Resistant starch, Amylose and Glycemic index were studied. RSM was used to optimize the level of cereals and pulses for quality soup stick product, the

Table 4.23 Experimental design for soup sticks

	Factor 1	Factor 2	Factor 3	Factor 4	Response 1	Response 2	Response 3	Response 4
Run	A:chick pea	B:kulthi	C:rice bean	D:wheat	STARCH	R.STARCH	AMYLOSE	GI
	G	G	G	G	%	%	%	%
1	0	-1	0	-1	18.71	2.64	7.81	24.5
2	-1	0	0	-1	18.78	2.65	7.98	21.59
3	0	1	0	1	18.23	2.6	7.63	22.56
4	1	0	-1	0	18.07	2.55	7.42	24.82
5	1	0	1	0	18.42	2.98	7.34	23.47
6	-1	-1	0	0	18.34	2.87	7.32	17.98
7	0	1	0	-1	18.9	2.58	7.64	21.95
8	1	1	0	0	18.28	2.99	7.44	18.65
9	1	0	0	1	18.34	2.67	7.32	22.34
10	0	-1	1	0	18.65	2.98	7.66	22.23
11	0	1	1	0	18.55	2.78	7.58	18.09
12	0	0	-1	1	18.5	2.77	7.45	21.84
13	0	0	1	-1	18.6	2.5	7.86	18.65
14	-1	0	1	0	18.13	2.67	7.71	18.81
15	0	0	0	0	18.65	2.76	7.65	18.87
16	1	0	0	-1	18.39	2.55	7.34	25.45
17	0	-1	0	1	18.87	2.78	7.32	23
18	0	1	-1	0	18.59	2.66	7.42	25.34
19	0	0	0	0	18.34	2.98	7.38	23.45
20	-1	1	0	0	18.73	2.5	7.86	26.32
21	0	0	-1	-1	18.53	2.34	7.52	27.87
22	0	-1	-1	0	18.44	2.79	7.35	24.66
23	0	0	0	0	18.55	3.02	7.56	24.34
24	0	0	0	0	18.74	3.1	7.46	25.05
25	0	0	0	0	18.7	3	7.23	26.08
26	0	0	1	1	18.34	2.67	7.27	24.34
27	1	-1	0	0	18.74	2.71	7.32	27.62
28	-1	0	0	1	17.98	2.33	7.45	25.34
29	-1	0	-1	0	18.35	2.47	7.23	24.76

optimized products were then assessed for storage studies of 120 days. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

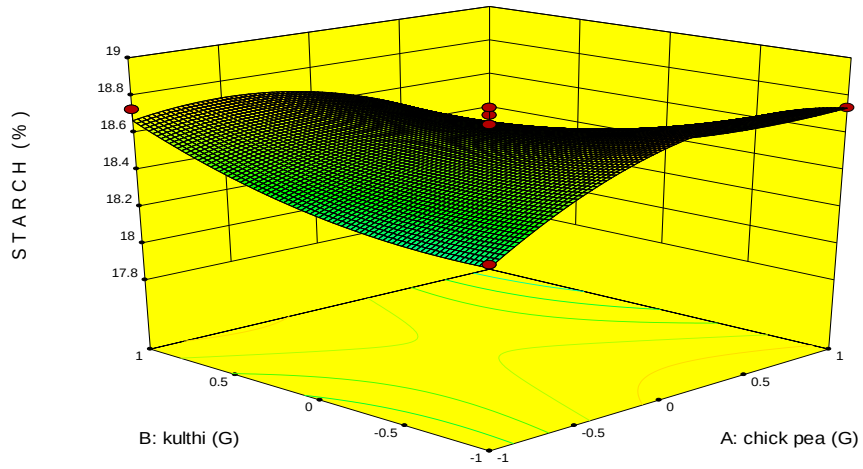
Table 4.24 Data analysis of soup sticks

Parameters	Starch	Resistant Starch	Amylose	Glycemic Index
β_0	+18.60	+2.97	+7.46	+23.56
Chick pea-A	-5.83	+0.080	-0.11	+0.63
Horse gram-B	-0.04	-0.055	+0.066	-0.59
Rice bean-C	+0.02	+0.083	+0.086	-1.98
wheat -D	-0.14	+0.047	-0.14	-0.05
A^2	-0.21	-0.16	-0.022	-0.14
B^2	+0.10	-0.044	+0.056	-0.67
C^2	-0.13	-0.13	-0.012	-0.43
D^2	-4.25	-0.27	+0.086	+0.14
AB	-0.21	+0.16	-0.10	-4.33
AC	+0.14	+0.058	-0.14	+1.15
AD	+0.19	+0.11	+0.13	-1.71
BC	-0.06	-0.018	-0.038	-1.20
BD	-0.21	-0.030	+0.12	+0.53
CD	-0.06	-0.065	-0.13	+2.93
R-Squared	0.8734	0.8355	0.8041	0.8428
Lack of fit (F-value)	*0.9066*	*0.6368*	*0.8507*	*0.9998*
Adequate precision	10.955	7.008	7.082	8.590

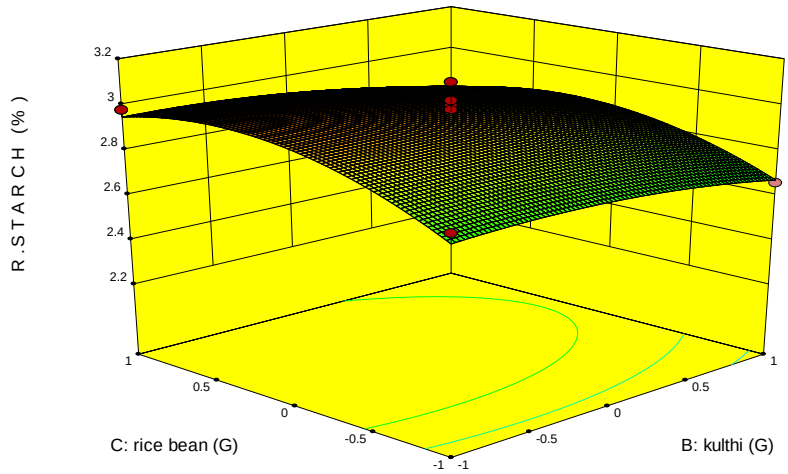
v. Data analysis of soup stick

In regression analysis of starch from soup sticks it was observed that the model had a non significant lack of fit and coefficient of determination for all the responses as 0.87, 0.83, 0.80, 0.84 while the adequate precision values were found as 10.95, 7.01, 7.01,8.6 for starch, resistant starch, amylose and glycemic index respectively. The constant values were found as 18.60, 2.97, 7.46 and 23.56 for starch, resistant starch, amylose and glycemic index respectively. In response starch

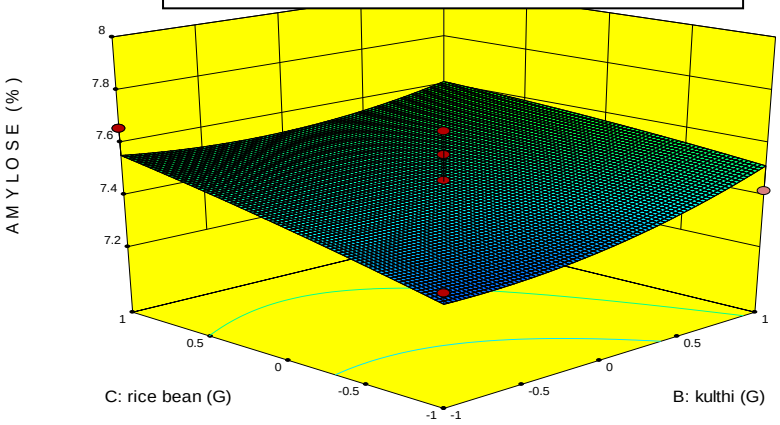
variable A showed a significant (*p≤0.001*) negative linear effect, the quadratic coefficient of variable D had a significant (*p≤0.05*) negative quadratic and in interaction of variable AC and AD displayed a significant (*p≤0.05*) positive effect on starch. In resistant starch all variable had a significant (*p≤0.001*) positive linear effect except B and quadratic coefficient of all the variables had little negative effect. In the interaction of variables, variable AB and AC variables had a significant (*p≤0.05)* positive effect. In experimental design amylose response showed significant (*p≤0.001*) negative linear effect with variable A and D while significant (*p≤0.001*) positive linear effect with found to be shown by B and C. But the quadratic coefficient of variable A and C had a significant (*p≤0.05*) negative quadratic correlation while variable B and D had significant (*p≤0.05*) positive quadratic effect. In glycemic index variable A had a significant (*p≤0.001*) positive linear effect and quadratic coefficient of variable D had a significant (*p≤0.05*) positive quadratic effect on glycemic index. In interaction of variables, AB, AD and BC depicted a significant (*p≤0.05*) negative effect on the glycemic index. . The response surface plot as shown in Figure (4.4)



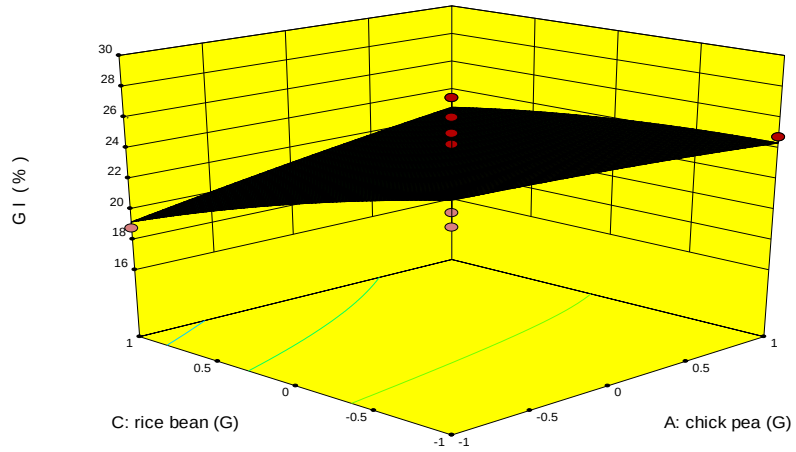
1. B (Kulthi) : A (Chick pea)



2. B (Kulthi) : C (Rice bean)



3. B (Kulthi) : C (Rice bean)



4. A (Chick pea) : C (Rice bean)

Figure4.4: Response surface plots for soup sticks

vi. Figure 4.4 displayed the surface plots for responses starch, resistant starch, amylose content and glycemic index respectively. In case of response starch and amylose it is clear from the graphs (plot.1 & Plot.3) variable A (chick pea) and variable B (kulthi) both have increasing effect but, the effect is non significant. Resistant starch (Plot.2) has the increasing effect with the increase of kulthi and rice bean but the increase is more significant with rice bean. In case of plot .4 reveals that there is significant negative effect on the glycemic index with the increase in rice bean.

4.2.3 Preparation of soup sticks

Table 4.25 Experimental dsign for rusk

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Response 1	Response 2	Response 3	Response 4	Response 5
Run	A:oat	B:pearl millet	C:finger millet	D:sorghum	E:wheat	moisture	ash	fat	fiber	Protein
	G	G	G	G	G	%	%	%	%	%
1	1	0	0	-1	0	3.9	4.72	6.45	0.22	6.89
2	0	0	-1	0	1	3.87	4.67	6.54	0.23	6.56
3	1	0	0	0	-1	3.88	4.55	6.45	0.25	6.98
4	1	0	0	0	1	3.94	4.84	6.35	0.27	7
5	0	0	0	0	0	3.96	4.78	6.44	0.29	6.58
6	0	1	-1	0	0	3.92	4.7	6.98	0.32	6.65
7	0	0	0	0	0	3.91	4.67	6.89	0.43	6.9
8	-1	0	0	-1	0	3.75	4.89	6.76	0.36	6.99
9	0	1	0	0	-1	3.89	4.88	6.65	0.23	6.45
10	1	0	0	1	0	3.67	4.75	6.9	0.2	6.65
11	-1	0	-1	0	0	3.88	4.63	7.12	0.29	6.88
12	0	-1	1	0	0	3.78	5	7.33	0.34	6.34
13	-1	-1	0	0	0	3.98	4.9	7.06	0.33	6.12
14	0	0	1	0	1	3.87	4.89	6.78	0.43	6.89
15	0	-1	0	0	1	4.12	4.88	6.9	0.21	6
16	0	0	1	0	-1	3.85	4.78	6.92	0.16	6.14
17	0	1	0	-1	0	3.91	4.67	6.91	0.18	6.05
18	1	0	1	0	0	3.89	4.56	6.82	0.24	6.76
19	0	0	-1	0	-1	3.76	4.72	6.89	0.41	6.89
20	0	0	0	-1	1	3.87	4.67	6.49	0.23	6.99
21	1	1	0	0	0	3.9	4.7	6.88	0.2	6.43
22	-1	0	0	0	1	3.91	5	6.68	0.25	6.45
23	0	0	0	0	0	3.92	4.75	7	0.28	6.32
24	0	-1	-1	0	0	3.57	4.68	6.87	0.29	5.98
25	0	0	-1	1	0	3.87	4.75	6.87	0.3	5.87
26	0	-1	0	-1	0	3.76	4.87	6.76	0.19	5.55
27	0	0	0	1	-1	3.82	4.64	6.56	0.2	6.56
28	0	0	0	0	0	3.76	4.67	6.34	0.15	6.94
29	-1	1	0	0	0	3.45	4.9	6.54	0.17	6.95
30	-1	0	1	0	0	3.49	4.98	6.75	0.32	5.98
31	0	0	0	1	1	3.87	4.67	6.98	0.31	7.13
32	0	0	0	0	0	3.89	4.87	6.23	0.25	6.67
33	-1	0	0	1	0	3.89	4.45	6.52	0.28	6.66
34	1	-1	0	0	0	3.58	4.65	6.56	0.29	6.6
35	0	-1	0	1	0	3.87	4.55	6.92	0.33	6.43
36	0	1	0	0	1	3.78	4.56	6.54	0.24	6.46
37	-1	0	0	0	-1	3.98	4.76	6.77	0.38	7.05
38	0	-1	0	0	-1	3.99	4.35	6.88	0.3	7.02
39	0	1	0	1	0	3.78	4.87	6.76	0.2	6.45
40	0	0	1	-1	0	3.65	4.67	6.94	0.28	6.34
41	0	1	1	0	0	3.55	4.5	6.89	0.13	5.99
42	0	0	0	-1	-1	3.9	4.45	6.98	0.32	6.12
43	0	0	1	1	0	3.89	4.43	6.77	0.3	6.43
44	1	0	-1	0	0	3.63	4.56	6.78	0.34	6.56
45	0	0	-1	-1	0	3.87	4.45	6.55	0.26	6.85
46	0	0	0	0	0	4	4.65	6.46	0.21	6.33

i. Experimental design

Response surface methodology (RSM) was used to design the experiment. Central composite Box Behken design was done for five independent variables of cereals as shown in Table 4.25. The high and low levels of five independent variables were chosen as discussed in Table. Each variable was tested by performing the preliminary trials and literature. The Box Behken design for the five independent variables at five levels each was performed for proximate composition. Product responses including Moisture (%), Ash (%), Fat (%), Fiber (%) and Protein (%) were studied. RSM was used to optimize the level of cereals for quality rusk product, the optimized products were then assessed for storage studies of 120 days. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

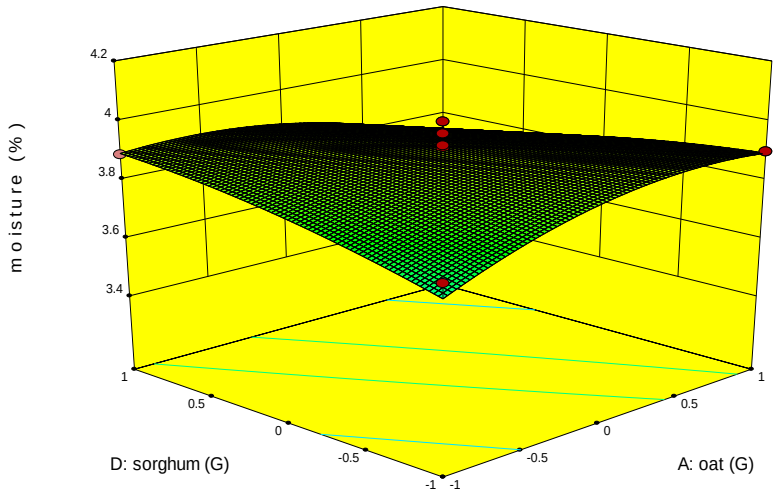
Table 4.26 Data analysis of rusk

Parameters	Moisture	Ash	Fat	Fiber	Protein
β_0	+3.91	+4.73	+6.56	+0.27	+6.62
Oat –A	+3.75	-0.07	-0.06	-0.023	+0.05
Pearl millet –B	-0.03	-6.25	-0.07	-0.04	+0.09
Finger millet –C	-0.02	+0.04	+0.04	-0.01	-0.09
Sorghum –D	+3.12	-0.02	+0.03	+5.00	+0.02
Wheat –E	+0.01	+0.07	-0.05	-5.00	+0.02
A^2	-0.07	+0.03	+0.02	+7.08	+0.16
B^2	-0.06	+0.02	+0.19	-0.03	-0.30
C^2	-0.11	-0.04	+0.22	+0.03	-0.16
D^2	-0.03	-0.08	+0.08	-0.01	-0.09
E^2	+0.06	-9.58	+0.02	+9.58	+0.14
AB	+0.21	+0.01	+0.21	+0.02	-0.25
AC	+0.16	-0.09	+0.10	-0.03	+0.27
AD	-0.09	+0.12	+0.17	+0.01	+0.02
AE	+0.03	+0.01	-2.50	+0.04	+0.15
BC	-0.15	-0.13	-0.14	-0.06	-0.25
BD	-0.06	+0.13	-0.08	-0.03	-0.12
BE	-0.06	-0.21	-0.03	+0.02	+0.26
CD	+0.06	-0.14	-0.12	-5.00	+0.27
CE	-0.02	+0.04	+0.05	+0.11	+0.27
DE	+0.02	-0.05	+0.23	+0.05	-0.07
R-Squared	0.7964	0.6777	0.6682	0.6655	0.6247
Lack of fit (F-value)	*0.5030*	*0.1784*	*0.9986*	*0.9976*	*0.3686*
Adequate precision	8.399	6.895	7.145	7.606	5.867

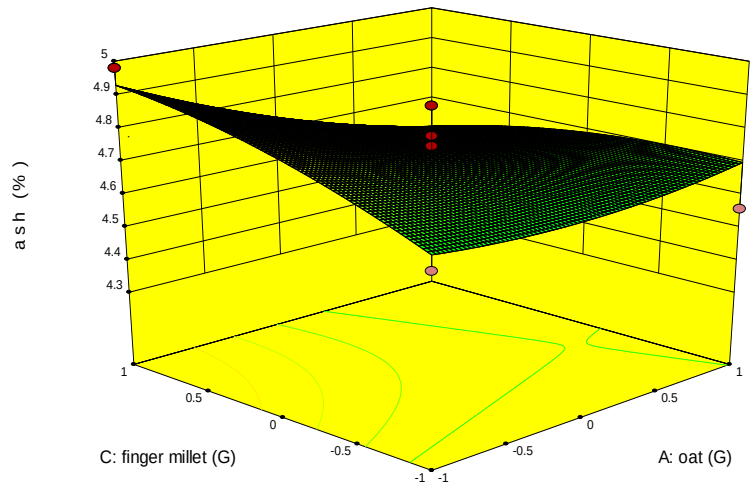
ii. Data analysis of rusk

Regression analysis of rusk model reveals that all the responses have non significant lack of fit test. Coefficient of determination (R^2) were found as 0.79, 0.68, 0.67, 0.66, 0.62 and adequate precision as 8.39, 6.89, 7.14, 7.61,5.87 for moisture, ash, fat, fiber and protein respectively. The constant values were depicted as 3.91, 4.73, 6.56, 0.27, and 6.62 for moisture, ash, fat, fiber, and protein respectively. Variable A and D had a significant ($p \leq 0.001$) positive linear effect and the quadratic coefficient of all the variables had significant ($p \leq 0.05$) negative quadratic effect except variable E on moisture content. Interaction of variable AB and AC showed a significant ($p \leq 0.05$) positive effect while BC had a significant ($p \leq 0.05$) negative effect on moisture. For response Ash variable B had a significant ($p \leq 0.001$) negative linear effect significant ($p \leq 0.05$) positive quadratic effect. The quadratic coefficient of variable E had a significant ($p \leq 0.05$) negative corelation. In interaction of variables BE and CD showed significant ($p \leq 0.05$) negative effect while BD had significant ($p \leq 0.05$) positive effect on ash. Experimental design showed that in Fat response variable A, C and E had significant ($p \leq 0.001$) negative linear effect while B and D had significant ($p \leq 0.001$) positive linear effect. Quadratic coefficient of all the variables had a significant ($p \leq 0.05$) positive quadratic effect. In interaction of variables AB and DE had the significant ($p \leq 0.05$) positive effect while AE showed a significant ($p \leq 0.05$) negative effect. For response fiber variable D displayed significant ($p \leq 0.001$) positive linear and E had significant ($p \leq 0.001$) negative linear effect. Quadratic coffecient of variable A and E had a very significant ($p \leq 0.05$) positive corelation. For response protein variable A, B, D and E showed significant ($p \leq 0.001$) positive linear effect C had significant ($p \leq 0.001$) negative linear effect. Quadratic coefficient of variable A and D had significant ($p \leq 0.05$) positive while B, C and E displayed the significant ($p \leq 0.05$) negative quadratic effect. In combination of variables AC, BE, CD and CE displayed a significant ($p \leq 0.05$) positive effect while AB had a significant ($p \leq 0.05$) negative effect on response. The response surface plot as shown in Figure (4.5).

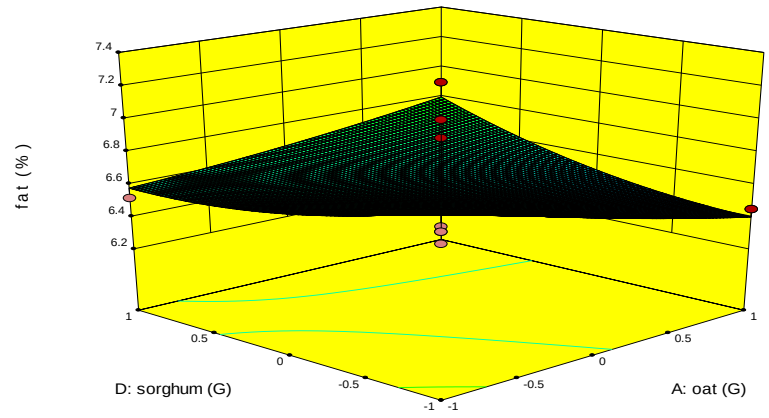
Response surface plot for rusk



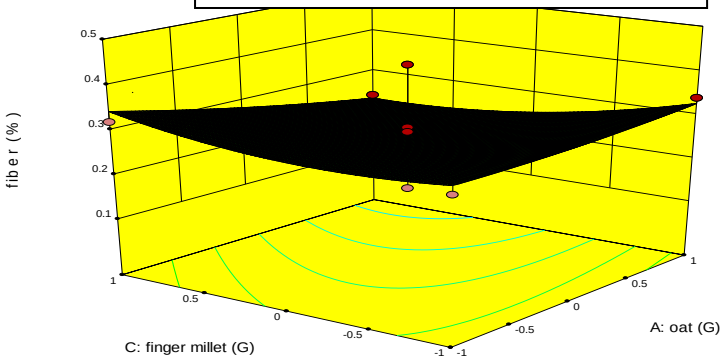
1. A (Oat) : D (Sorghum)



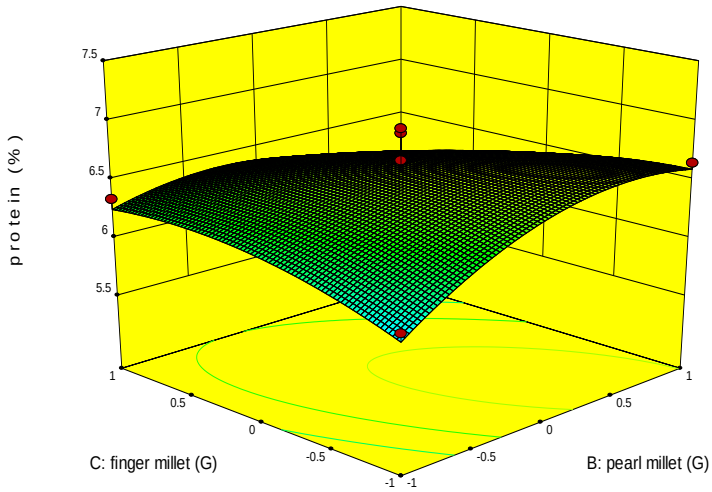
2. A (Oat) : C (Finger millet)



3. A (Oat) : D (Sorghum)



4. A (Oat) : C (Finger millet)



5. B (Pearl millet) : C (Finger millet)

Figure 4.5: Response Surface Plots for Rusk

iii. Figure 7 reveals the surface plot for responses moisture, ash, fat, fiber and protein respectively. Plot.1 shows that with the increase in oat and sorghum there is increase in moisture but the effect is not significant. For response ash it is observed that with the increase of finger millet and oat there is increase in ash content the increase is significant with finger millet. In case of fiber (Plot.4) with the increase of oat and finger millet fiber content is increase but the effect is not significant. In response protein (Plot.5) with the increase in finger millet and pearl millet protein content also increase but the increase is more significant with pearl millet.

Table 4.27 Experimental design for rusk

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Response 1	Response 2	Response 3	Response 4
Run	A:oat	B:pearl millet	C:finger millet	D:sorghum	E:wheat	starch	R.starch	Amylose	GI
	G	g	G	g	g	%	%	%	%
1	1	0	-1	0	0	28.52	3.59	8.51	36
2	-1	0	0	1	0	28.65	3.69	9.03	40
3	-1	0	-1	0	0	28.56	3.98	8.95	38
4	0	0	0	0	0	28.97	3.45	8.99	37
5	0	1	-1	0	0	28.45	3.69	9.02	39
6	0	0	0	0	0	28.66	3.75	8.56	40
7	0	0	-1	0	1	28.9	3.01	8.89	43
8	0	0	1	0	-1	28.17	3.99	8.98	32
9	0	0	0	-1	1	28.74	4.12	8.23	34
10	0	-1	0	0	1	28.5	4.05	9.03	35
11	0	0	0	0	0	28.55	4	9.13	31
12	-1	-1	0	0	0	28.53	3.59	9.32	36.77
13	0	-1	0	-1	0	28.34	3.67	8.27	29
14	0	-1	1	0	0	27.86	3.89	8.45	38
15	-1	0	1	0	0	27.99	3.75	8.97	38.77
16	1	1	0	0	0	28.97	3.73	8.65	36.4
17	0	0	0	0	0	28.45	3.98	8.55	47
18	0	0	-1	0	-1	28.54	3.99	8.34	35
19	0	0	0	-1	-1	28.4	3.45	8.3	34
20	0	-1	0	0	-1	28.12	3.25	8.55	31
21	0	1	1	0	0	28.67	3.76	8.76	39
22	0	0	-1	1	0	28.03	3.69	8.88	38
23	0	0	1	1	0	27.68	3.89	8.95	40.13
24	1	0	1	0	0	28.45	4.02	8.34	28
25	1	0	0	0	-1	28.4	3.67	8.45	29
26	1	0	0	-1	0	28.77	3.98	8.34	27
27	0	0	1	-1	0	28.01	3.55	9	26
28	1	0	0	0	1	28.79	3.87	8.47	32.67
29	-1	0	0	0	-1	28.34	4.03	7.95	39
30	1	-1	0	0	0	27.86	3.57	7.45	31.15
31	1	0	0	1	0	27.99	3.21	8.94	39
32	0	0	0	0	0	28.34	3.33	9.04	34
33	0	0	0	0	0	28.45	3.45	8.33	32
34	0	0	-1	-1	0	28.54	4.12	8.45	45
35	0	1	0	0	1	28.4	2.97	8.95	34
36	0	-1	0	1	0	28.12	3.61	8.87	36
37	0	0	0	1	1	28.67	2.99	8.9	39
38	0	1	0	-1	0	28.96	3.56	8.94	33
39	0	1	0	0	-1	28.62	3.76	8.56	32
40	0	0	1	0	1	28.01	3.99	8.45	30
41	-1	0	0	0	1	28.32	3.76	9.04	31
42	-1	1	0	0	0	27.98	3.67	8.88	35.02
43	-1	0	0	-1	0	28.03	3.47	8.95	34
44	0	-1	-1	0	0	28.12	4.23	8.45	35
45	0	1	0	1	0	28.3	3.39	8.98	36
46	0	0	0	1	-1	28.45	3.92	8.45	37

iv. Experimental design for rusk

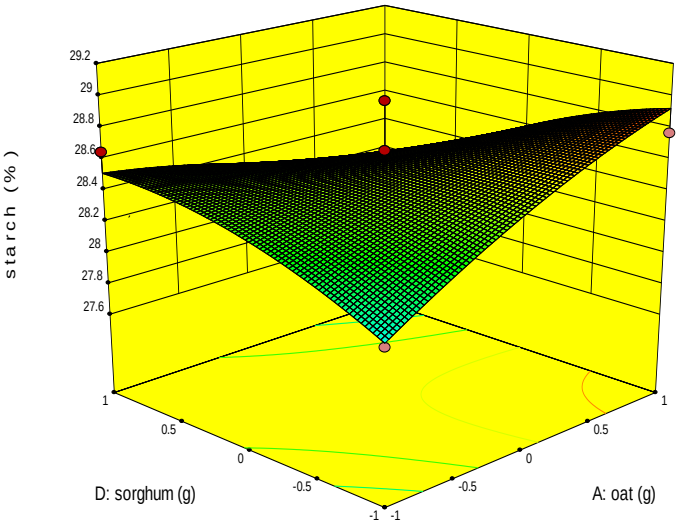
Box Behken design was done for five independent variables of cereals as shown in Table 4.27. Response surface methodology (RSM) was used to design the experiment. The high and low levels of five independent variables were chosen as discussed in Table 3.3. Each variable was tested by performing the preliminary trials and literature. The design for the five independent variables at four levels each was performed for starch composition. Product responses including Starch, Resistant Starch, Amylose and Glycemic index were studied. RSM was used to optimize the level of cereals for quality rusk product, the optimized products were then assessed for storage studies of 120 days. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

v. Data analysis of rusk

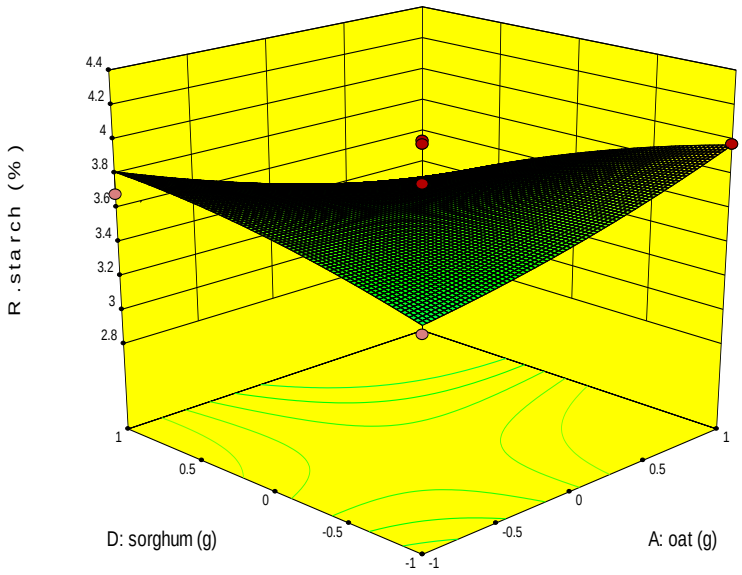
Regression analysis of rusk starches model shows that there are five independent variables and four responses. Lack of fit values for all the response was non significant and the constant values as 28.57, 3.66, 8.77, 36.83 for starch, resistant starch, amylose and glycemic index respectively. The coefficient of determination R^2 and adequate precision values was observed as 0.78, 0.70, 0.67, 0.63 and 9.59, 7.27, 7.13, 6.50 for starch, resistant starch, and amylose and glycemic index respectively. For response starch, variable A, B and E showed a significant ($p \leq 0.001$) positive linear while C and D had a significant ($p \leq 0.001$) negative linear effect. Quadratic coefficient of all the variables had significant ($p \leq 0.05$) negative *quadratic* effect except variable E. In interaction of variable it is observed that variable AB had a significant ($p \leq 0.05$) positive effect on starch. In case of response resistant starch all the variables had significant ($p \leq 0.001$) negative linear effect except variable C. Quadratic coefficient of variable A and C showed a significant ($p \leq 0.05$) positive quadratic effect while BC and D had significant ($p \leq 0.05$) negative quadratic effect. In combination of variables AD displayed a significant ($p \leq 0.05$) negative effect while

Table 4.28 Data analysis of rusk

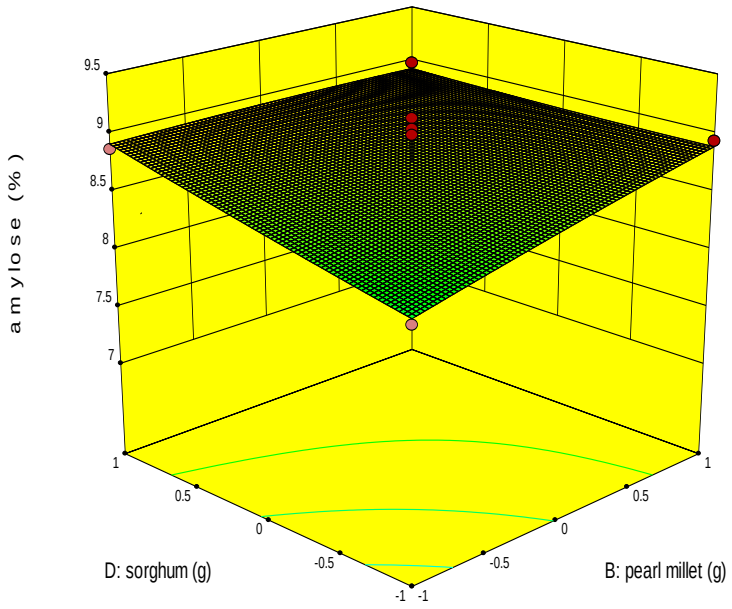
Parameters	Starch	Resistant Starch	Amylose	Glycemic Index
β_0	+28.57	+3.66	+8.77	+36.83
Oat-A	+0.08	-0.02	-0.25	-2.08
Pearl millet-B	+0.18	-0.08	+0.15	+0.78
Finger millet-C	-0.18	+0.03	+0.03	-2.32
Sorghum-D	-0.12	-0.01	+0.16	+2.70
wheat-E	+0.08	-0.08	+0.15	+0.60
A^2	-0.08	+0.05	-0.09	-1.64
B^2	-0.11	-0.055	-0.02	-1.26
C^2	-0.22	+0.18	+5.62	+0.79
D^2	-0.12	-0.06	+0.01	-0.36
E^2	+0.02	-0.01	-0.15	-1.98
AB	+0.42	+0.02	+0.41	+1.75
AC	+0.13	+0.16	-0.05	-2.19
AD	-0.35	-0.25	+0.13	+1.50
AE	+0.10	+0.12	-0.27	+2.92
BC	+0.12	+0.10	-0.06	-0.75
BD	-0.11	-0.03	-0.14	-1.00
BE	-0.15	-0.40	-0.02	-0.50
CD	+0.04	+0.19	-0.12	+5.28
CE	-0.13	+0.25	-0.27	-2.50
DE	-0.03	-0.40	+0.13	+0.50
R-Squared	0.7821	0.7013	0.6714	0.6386
Lack of fit (F-value)	*0.7098*	*0.8793*	*0.7837*	*0.9948*
Adequate precision	9.588	7.273	7.134	6.500



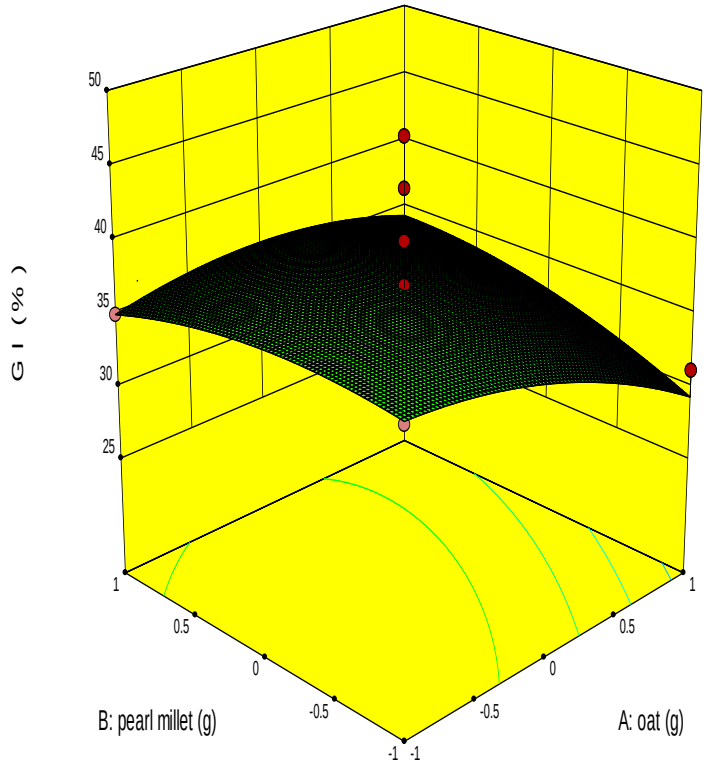
1. A (Oat) : D (Sorghum)



2. A (Oat) : D (Sorghum)



3. B (Pearl Millet) : D (Sorghum)



4. A (Oat) : B (Pearl millet)

Figure 4.6: Response surface plots for rusk

CE had a significant ($p \leq 0.05$) positive effect on response resistant starch. For response amylose all the variable displayed the significant ($p \leq 0.001$) positive linear effect except variable A while the Quadratic coefficient of variable A, B and E had a significant ($p \leq 0.05$) negative quadratic effect. In interaction of variables, AB had a significant ($p \leq 0.05$) positive effect, while AC and CE showed significant ($p \leq 0.05$) negative effect on amylose. In regression analysis of response glycemic index, variable A and C had a significant ($p \leq 0.001$) positive linear effect. The quadratic coefficient of variable A, B and E had a significant ($p \leq 0.05$) negative correlation. In interaction of variables, AB, BD and CE showed significant ($p \leq 0.05$) negative effect while CD had very significant ($p \leq 0.05$) positive effect on response. . The response surface plot as shown in Figure (4.6).

vi. Figure 4.6 depicts the surface plots for responses starch, resistant starch, amylose and glycemic index respectively. In case of starch (Plot.1) and resistant starch (Plot.2) it is observed that with the increase of sorghum and oat there is increase in starch and resistant starch content but the increase is more significant with oat. For response amylose (Plot.3) there is increase with the increase in pearl millet and sorghum but, the effect is non significant. Plot.4 reveals the effect on glycemic index, with the increase in oat there is decrease in glycemic index.

4.2.3 Preparation of kurkure

i. Experimental design for kukure preparation

Response surface methodology (RSM) was used to design the experiment. Box Behken design was done for eight `independent variables of cereals and pulses as shown in Table 4.29 . The high and low levels of eight independent variables was chosen. Each variable were tested by performing the preliminary trials and literature. The Box Behken design for the eight independent variables at five levels each was performed for proximate composition. Product responses including Moisture (%), Ash (%), Fat(%), Protein (%), Fiber (%) were studied. RSM was used to optimize the level of cereals and pulses for quality kurkure product, the optimized products were then assessed for storage studies of 120 days. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a

Table 4.29 Experimental design for kurkure

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Response 1	Response 2	Response 3	Response 4	Response 5
Run	A:oat	B:pearl millet	C:finger millet	D:sorghum	E:chickpea	F:rice bean	G:kulthi	H:wheat	Moisture	ash	Fat	fiber	protein
	G	G	G	G	G	G	G	G	%	%	%	%	%
1	1	1	-1	-1	0	0	0	0	2.61	6.12	0.23	0.29	3.27
2	1	0	-1	0	-1	0	1	0	2.87	6.7	0.45	0.45	2.52
3	-1	0	1	0	0	1	0	-1	2.55	6.44	0.23	0.43	2.63
4	0	0	0	0	0	0	0	0	2.45	6.23	0.34	0.23	2.73
5	-1	1	0	0	0	0	-1	1	2.78	6.76	0.29	0.43	2.87
6	0	0	0	0	-1	-1	-1	-1	2.89	6.45	0.7	0.56	2.9
7	0	0	-1	1	-1	1	0	0	2.9	6.88	1.46	0.78	2.91
8	0	0	1	1	0	0	-1	-1	2.67	6.9	1.47	0.1	2.45
9	0	-1	1	0	0	-1	1	0	2.13	6	0.9	0.32	2.71
10	1	0	1	0	0	-1	0	-1	2.09	6.12	1	0.43	2.78
11	1	1	1	1	0	0	0	0	2	6.23	0.45	0.54	2.87
12	0	1	0	1	0	-1	0	-1	2.52	6.45	0.43	0.64	2.9
13	-1	-1	0	0	1	1	0	0	2.63	5.99	0.23	0.85	2.32
14	0	0	0	0	0	0	0	0	2.73	7.01	0.43	0.76	2.67
15	0	-1	0	-1	-1	0	-1	0	2.87	7.04	0.56	0.23	2.98
16	0	1	1	0	0	1	1	0	2.9	6.25	0.78	0.94	3.21
17	-1	1	0	0	1	-1	0	0	2.91	6.54	0.1	0.92	2.77
18	0	0	0	0	1	-1	1	-1	2.45	6.34	0.2	0.12	2.76
19	0	0	0	0	0	0	0	0	2.71	6.76	0.32	0.15	2.79
20	1	0	0	1	0	-1	-1	0	2.78	6.89	0.43	0.19	2.7
21	1	0	-1	0	1	0	-1	0	2.87	6.99	0.54	0.34	2.98

22	0	1	-1	0	0	-1	1	0	2.9	6.34	0.64	0.89	3.13
23	1	-1	-1	1	0	0	0	0	2.32	6.21	0.85	0.98	2.89
24	-1	0	1	0	1	0	-1	0	2.67	6.11	0.76	0.12	2.9
25	0	0	0	0	0	0	0	0	2.99	6.09	0.94	0.15	2.67
26	0	0	0	0	1	1	1	1	3.12	6.84	0.92	0.63	2.99
27	-1	-1	0	0	-1	-1	0	0	2.13	6.34	0.12	0.34	3.12
28	1	1	0	0	0	0	1	1	2.31	6.45	0.15	0.89	2.58
29	0	-1	0	1	-1	0	1	0	2.45	6.78	0.19	0.98	2.78
30	0	1	1	0	-1	0	0	-1	2.65	6.66	0.34	0.58	2.94
31	-1	-1	0	0	0	0	-1	-1	2.78	6.7	0.46	0.76	2.65
32	0	0	-1	-1	1	1	0	0	2.98	6.34	0.98	0.54	3.27
33	0	1	1	0	0	-1	-1	0	3.21	6.23	0.79	0.43	2.98
34	0	0	0	0	0	0	0	0	2.87	6.12	0.67	0.34	3.21
35	1	0	0	-1	-1	0	0	1	2.14	6.09	0.94	0.65	2.87
36	-1	0	0	1	1	0	0	-1	2.56	6.04	0.56	0.78	2.14
37	0	0	1	-1	0	0	1	-1	2.09	6.67	0.76	0.57	2.56
38	-1	0	0	-1	1	0	0	1	2.96	6.99	0.45	0.99	2.66
39	0	0	-1	-1	0	0	-1	-1	3.1	6.12	0.56	0.45	2.96
40	-1	0	-1	0	-1	0	-1	0	3.07	6.89	0.58	0.99	3.1
41	0	0	-1	1	1	-1	0	0	2.65	7.03	0.76	0.45	3.07
42	1	1	0	0	1	1	0	0	2.45	7.45	0.54	0.76	2.65
43	-1	-1	0	0	0	0	1	1	2.11	7.86	0.43	0.23	2.45
44	1	-1	0	0	-1	1	0	0	2.09	6.38	0.34	0.76	2.63
45	1	0	0	-1	0	-1	1	0	2.05	5.98	0.65	0.62	2.09
46	-1	0	0	-1	0	1	1	0	2.55	5.46	0.78	0.34	2.7

47	1	-1	1	-1	0	0	0	0	2.98	6.65	0.98	0.69	2.04
48	-1	0	1	0	0	-1	0	1	3.21	6.78	0.99	0.65	2.98
49	1	0	1	0	0	1	0	1	3.24	6.45	0.45	0.67	3.21
50	0	0	0	0	0	0	0	0	2.76	6.98	0.76	0.69	3.24
51	0	1	0	-1	0	-1	0	1	2.79	6.78	0.23	0.97	2.76
52	0	1	-1	0	1	0	0	-1	2.7	6.32	0.76	0.86	3.37
53	0	1	-1	0	0	1	-1	0	2.98	6.36	0.98	0.55	3.46
54	-1	0	0	1	-1	0	0	1	2.68	6.54	0.56	0.67	3.12
55	0	1	0	1	0	1	0	1	2.89	6.98	0.45	0.3	3.33
56	1	-1	0	0	0	0	-1	1	2.9	6.57	0.54	0.59	3.05
57	0	0	0	0	1	-1	-1	1	2.99	6.45	0.34	0.65	2.98
58	-1	0	0	1	0	1	-1	0	2.78	6.9	0.32	0.64	2.96
59	1	0	0	-1	1	0	0	-1	2.67	6.09	0.65	0.16	2.87
60	0	1	1	0	1	0	0	1	2.55	5.99	0.67	0.75	2.98
61	0	-1	0	1	0	-1	0	1	2.54	5.45	0.69	0.34	2.99
62	-1	-1	1	1	0	0	0	0	2.35	5.67	0.97	0.23	2.97
63	1	0	1	0	-1	0	-1	0	2.15	5.23	0.86	0.21	2.94
64	0	-1	0	1	1	0	-1	0	2.23	7.03	0.55	0.2	2.91
65	0	0	1	-1	1	-1	0	0	3.11	7.56	1.19	0.3	2.89
66	0	1	-1	0	-1	0	0	1	3.12	7	0.76	0.12	2.99
67	1	0	0	1	0	1	1	0	3.33	5.89	0.59	0.69	2.97
68	0	-1	0	-1	0	-1	0	-1	3.05	6.9	0.65	0.07	2.94
69	-1	1	1	-1	0	0	0	0	2.98	6.89	0.74	0.5	2.91
70	0	0	-1	1	0	0	-1	1	2.96	6.56	0.56	0.58	2.89
71	1	0	-1	0	0	-1	0	1	2.87	6.34	0.87	0.23	2.56

72	0	0	0	0	-1	1	-1	1	2.98	6.24	0.99	0.44	3.04
73	-1	0	-1	0	1	0	1	0	2.99	6.55	0.34	0.56	3.21
74	0	-1	0	-1	0	1	0	1	2.97	6.23	0.56	0.87	3.11
75	0	-1	0	-1	1	0	1	0	2.94	6.85	0.76	0.56	2.37
76	0	-1	0	1	0	1	0	-1	2.91	6.67	0.68	0.87	3.01
77	0	1	0	1	-1	0	-1	0	2.89	6.87	0.79	0.96	2.95
78	-1	0	0	1	0	-1	1	0	2.56	6.7	0.91	0.57	2.47
79	0	-1	-1	0	0	1	1	0	3.04	6.33	0.94	0.98	2.76
80	1	1	0	0	-1	-1	0	0	2.73	6.01	0.45	0.45	2.81
81	1	-1	0	0	0	0	1	-1	2.59	5.75	0.35	0.98	2.13
82	1	0	0	1	1	0	0	1	3.05	5.78	0.9	0.38	2.19
83	-1	0	1	0	-1	0	1	0	2.51	7.34	0.7	0.63	3.02
84	0	1	0	1	1	0	1	0	3	6.94	0.95	0.45	3.11
85	0	1	0	-1	0	1	0	-1	2.76	6.23	0.76	0.45	3.38
86	-1	0	-1	0	0	-1	0	-1	3.33	6.14	0.34	0.43	3.65
87	1	-1	0	0	1	-1	0	0	3.25	6.79	0.65	0.23	2.87
88	0	-1	-1	0	1	0	0	1	2.76	6.99	0.76	0.43	2.67
89	0	0	0	0	0	0	0	0	2.55	6.97	0.46	0.56	2.47
90	0	0	0	0	1	1	-1	-1	2.78	6.87	0.44	0.78	2.76
91	0	0	0	0	-1	-1	1	1	2.75	6.98	0.5	0.61	2.81
92	-1	-1	-1	-1	0	0	0	0	2.8	6.54	0.54	0.15	2.6
93	1	1	0	0	0	0	-1	-1	2.83	6.76	0.87	0.19	2.65
94	0	0	1	-1	-1	1	0	0	2.85	6.54	0.55	0.34	3.02
95	1	0	0	1	-1	0	0	-1	2.9	6.45	0.66	0.85	2.54
96	0	1	0	-1	-1	0	1	0	2.28	6.34	0.34	0.29	3.28

97	0	1	0	-1	1	0	-1	0	2.47	6.22	0.22	0.43	3.12
98	0	0	-1	-1	-1	-1	0	0	2.76	6.92	0.98	0.32	2.87
99	0	-1	1	0	1	0	0	-1	2.81	7.03	0.87	0.3	2.67
100	1	0	0	-1	0	1	-1	0	2.13	7	0.78	0.28	2.89
101	-1	0	0	-1	-1	0	0	-1	2.19	6.56	0.9	0.25	3.01
102	0	-1	1	0	0	1	-1	0	3.02	6.34	0.45	0.98	3.45
103	0	-1	-1	0	0	-1	-1	0	3.11	6.57	0.65	0.85	3.33
104	0	0	-1	1	0	0	1	-1	3.52	6.88	0.76	0.66	3.25
105	0	0	1	1	1	1	0	0	3.08	6.98	0.84	0.34	2.76
106	-1	1	0	0	-1	1	0	0	2.87	6.99	0.44	0.22	3.14
107	1	0	1	0	1	0	1	0	2.67	6.75	0.65	0.98	2.78
108	-1	1	-1	1	0	0	0	0	2.89	6.7	0.76	0.87	2.75
109	-1	1	0	0	0	0	1	-1	3.01	6.87	0.45	0.78	2.8
110	0	-1	-1	0	-1	0	0	-1	3	6.45	0.34	0.9	2.83
111	0	0	0	0	-1	1	1	-1	2.76	6.33	0.37	0.45	2.85
112	0	0	1	1	0	0	1	1	2.89	6.34	0.85	0.65	2.9
113	0	0	1	-1	0	0	-1	1	3.36	6.15	0.29	0.61	2.95
114	0	0	1	1	-1	-1	0	0	2.78	6	0.43	0.65	3.21
115	0	0	-1	-1	0	0	1	1	2.34	7.98	1.09	0.66	3.09
116	-1	0	0	-1	0	-1	-1	0	3.11	7.54	0.3	0.45	3
117	0	-1	1	0	-1	0	0	1	2.64	7.3	0.28	0.87	3.56
118	-1	0	-1	0	0	1	0	1	2.76	7.32	0.25	0.45	3.07
119	1	0	-1	0	0	1	0	-1	2.88	7.07	0.98	0.65	3.07
120	0	0	0	0	0	0	0	0	2.89	6.87	0.85	0.6	3.12

measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

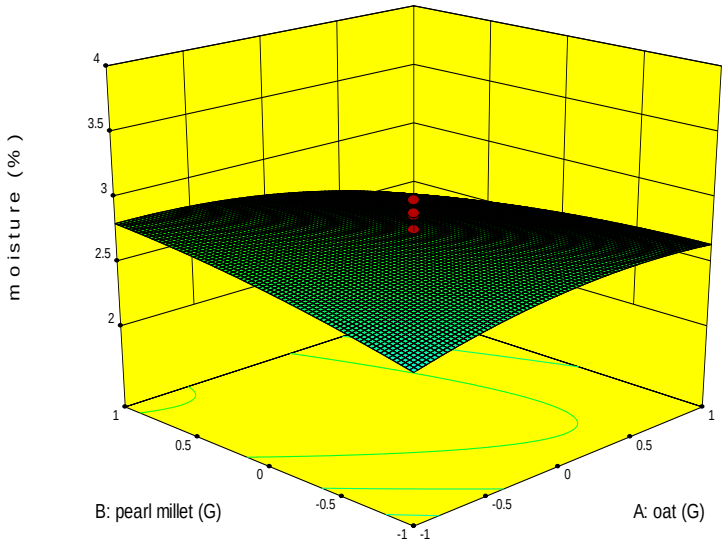
Table 4.30 Data analysis of kurkure

Parameters	Moisture	Ash	Fat	Fiber	Protein
β_0	+2.74	+6.63	+0.60	+0.44	+2.86
Oat –A	-0.05	-0.12	+0.06	-1.79	-0.06
Pearl millet –B	+0.03	+5.71	-0.02	-1.61	+0.09
Finger millet –C	-0.09	-0.09	+9.46	-0.03	-0.06
Sorghum –D	+0.02	-0.04	+0.02	+0.06	-8.39
Chick pea-E	+0.06	+0.03	+0.02	-0.01	-0.07
rice bean –F	+0.03	+0.02	+0.02	+0.06	+0.04
Kulthi-G	-0.08	-4.46	+5.89	+0.06	-0.08
Wheat- H	+0.03	+0.07	-0.01	+0.02	+0.04
A^2	-0.11	-0.09	-0.08	+0.01	-0.16
B^2	-0.05	-0.04	-0.09	+0.09	+0.04
C^2	+0.09	-1.60	+0.16	+0.04	+0.13
D^2	-0.03	-0.024	+0.11	-0.02	-0.03
E^2	-0.03	+0.06	-0.02	+0.01	+7.19
F^2	+0.09	-0.06	+6.12	+0.02	+0.09
G^2	+0.01	+0.03	-9.51	+0.04	-0.01
H^2	+0.05	+4.95	-0.01	+0.04	-0.01
AB	-0.15	-0.06	-0.08	-0.10	+7.92
AC	-0.05	-0.09	-0.10	+0.09	+0.02
AD	+0.071	+0.07	-0.03	-0.03	+0.05
AE	+0.072	+0.29	+0.04	-0.01	+0.09
AF	+2.29	+0.22	+0.06	+0.03	+0.05
AG	+0.02	-0.17	-0.12	+0.15	-1.46
AH	+0.02	-0.21	+4.17	+0.03	-0.03
BC	-0.08	-0.01	-0.03	+0.04	-0.07
BD	+0.13	+0.2	+0.06	-0.018	-0.15
BE	-0.21	-0.02	-0.06	+0.09	+2.92
BF	-0.02	+0.07	+0.08	-0.18	+0.09
BG	+0.05	+0.09	-0.01	+0.07	+0.16
BH	-4.58	-0.07	-0.05	-0.01	-0.05
CD	-0.05	-0.16	-0.03	-0.11	+0.07
CE	+0.05	+0.06	+0.15	-0.05	-0.11
CF	+0.07	+4.37	-0.16	+0.03	+0.01
CG	-0.070	+0.01	-0.05	+0.16	-0.05
CH	+0.21	-0.22	-0.05	+0.11	+0.15
DE	-0.13	+0.03	+0.08	-0.18	-0.07
DF	+0.09	+0.30	+0.02	-4.17	+4.17
DG	+0.18	-0.02	-0.04	-0.05	+0.03
DH	-0.03	-0.27	-0.02	-0.15	+0.02
EF	+0.04	-0.06	-0.03	+0.11	-0.03
EG	+0.08	-0.09	+0.15	+0.04	+0.01
EH	+6.87	-0.04	+8.54	+0.04	-0.07
FG	+0.18	-0.04	+7.92	-1.87	+0.07
FH	-0.03	-0.01	-0.04	-0.09	+0.12
GH	-0.02	+0.29	+0.15	+0.02	-0.06
R-Squared	0.6383	0.4825	0.5557	0.6821	0.6592
Lack of fit (F-value)	*0.1814*	*0.4977*	*0.6346*	*0.9318*	*0.9161*
Adequate precision	8.255	6.895	7.994	9.991	9.340

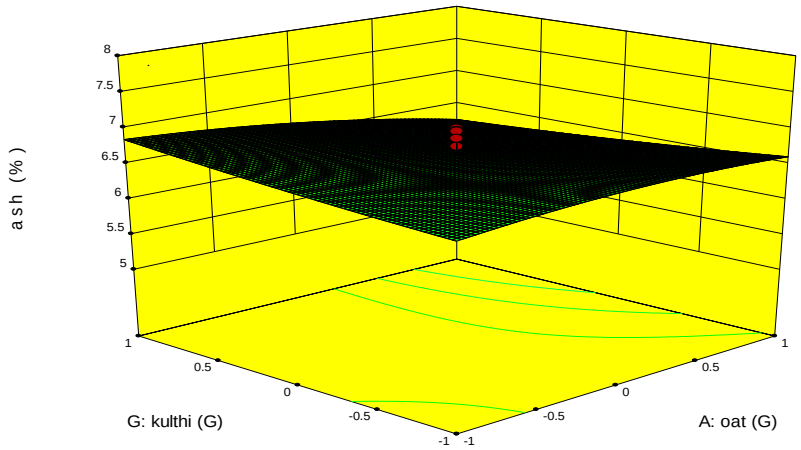
ii. Data analysis of kurkure

The results for estimated coefficient of the fitted polynomial are reported in table. In fitted model for kurkure there was eight independent variables and five responses. The constant values were observed as 2.74, 6.63, 0.60, 0.44, 2.86 for moisture, ash, fat, fiber, protein and the lack of fit values were observed non significant for all the responses. The coefficient of determination R^2 and adequate precision values were observed 0.64, 0.48, 0.55, 0.68, 0.66 and 8.25, 6.89, 7.99, 9.99, 9.34 for responses moisture, ash, fat, fiber, protein respectively. The regression analysis of responses moisture showed that all the variables had significant ($p \leq 0.001$) positive linear effect but quadratic coefficient of variable A, B, D and E displayed the significant ($p \leq 0.05$) negative quadratic effect. In case of combination of variables AF, CH and EH had a very significant ($p \leq 0.05$) positive effect while BH showed a significant ($p \leq 0.05$) negative effect on response. In case of response ash variable B showed a very significant ($p \leq 0.001$) positive linear while G had a very significant ($p \leq 0.001$) negative linear effect. The quadratic coefficient of variable C had significant ($p \leq 0.05$) negative correlation while H had significant ($p \leq 0.05$) positive quadratic effect on response. In interaction of variables CF displayed significant ($p \leq 0.05$) positive effect and DH had a significant ($p \leq 0.05$) negative effect. For response fat, variable C and G had a very significant ($p \leq 0.001$) positive linear effect. In case of quadratic coefficient of variables F showed a very significant ($p \leq 0.05$) positive quadratic effect while variable G had a very significant ($p \leq 0.05$) negative quadratic effect. In interaction of variables, AH, EH and FG had a very significant ($p \leq 0.05$) positive effect while CH had a significant ($p \leq 0.05$) negative effect. In regression analysis of response fiber variable A and B had a significant ($p \leq 0.001$) linear negative effect where as the quadratic coefficient of all the variables displayed a significant ($p \leq 0.05$) positive quadratic effect. In case of combination of variable, AG, CH and EF showed a significant ($p \leq 0.05$) positive effect where as DF and FG had a significant ($p \leq 0.05$) negative effect on response. For response protein variable D showed a very significant ($p \leq 0.001$) negative linear effect. The quadratic coefficient of variable E displayed a very significant ($p \leq 0.05$) positive quadratic effect on protein content. In interaction of variables, AB, BE and DF displayed a very significant ($p \leq 0.05$) positive effect on protein content whereas combination of variable AG showed a very significant ($p \leq 0.05$) negative effect on protein content. The response surface plot as shown in Figure (4.7)

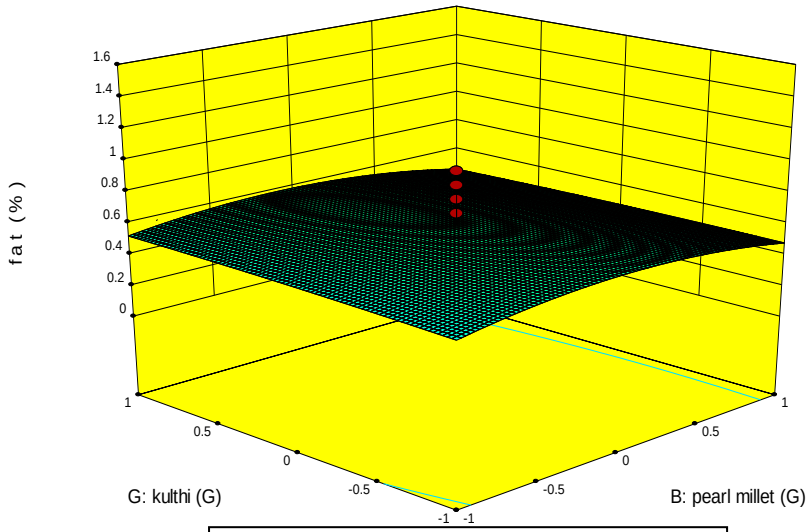
The response surface plots for Kurkure



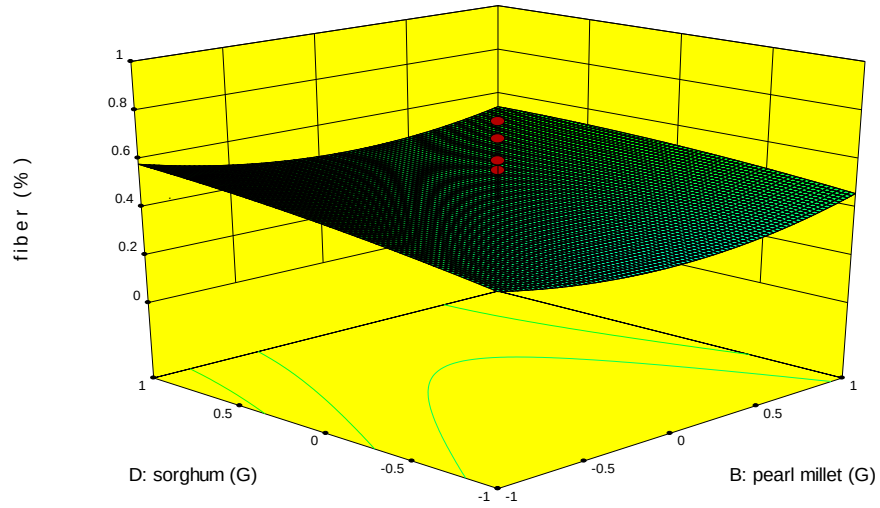
1. A (Oat) : B (Pearl millet)



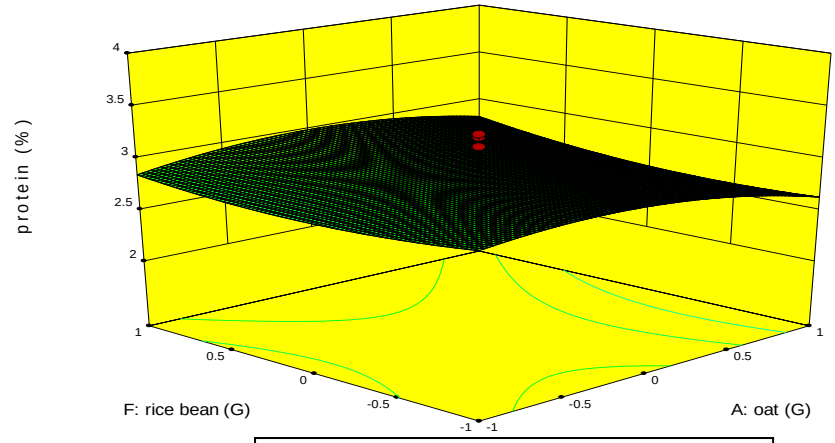
2. A (Oat) : G (Kulthi)



3. B (Pearl millet) : G (Kulthi)



4. B (Pearl millet) : D (Sorghum)



5. A (Oat) : F (Rice Bean)

Figure 4.7: Response surface plots for kurkure

iii. Figure 4.7 shows plots for responses moisture, ash, fat, fiber and protein respectively. In case of moisture and fat (plot.1 & 3) with the increase of oat and pearl millet there is increase in moisture and fat content but the effect is not significant. In plot.2 with the increase of oat and kulthi there is increase in ash content but the effect is non significant. For the response fiber (Plot.4) there is increase in fiber content with the increase in pearl millet and sorghum but, the increase is significant with sorghum. In case of protein (Plot.5) with the increase of oat and rice bean increase in protein content but the increase is non significant.

iv. Experimental design for kurkure

Response surface methodology (RSM) was used to design the experiment. Box Behken design was done for eight independent variables of cereals and pulses as shown in Table 4.31. The high and low levels of eight independent variables were chosen as discussed in Table. Each variable was tested by performing the preliminary trials and literature. The Box Behken design for the eight independent variables at four levels each was performed for starch composition. Product responses including Starch, resistant starch, amylose and glycemic index were studied. RSM was used to optimize the level of cereals and pulses for quality kurkure product, the optimized products were then assessed for storage studies of 120 days. A complete second order quadratic model was used for fitting the data and for checking the adequacy of the model by considering R^2 (the coefficient of multiple determination, that gives the measurement of the difference around the mean values as explained by the model), Adj R^2 (a measurement of the amount of variation around the mean explained by the model, adjusted for the number of terms in the model), predicted R^2 (a measurement of how correctly the model depicts a response value) and Fischer's F-test.

Table 4.31 Experimental design for Kurkure

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Response 1	Response 2	Response 3	Response 4
Std	Run	A:oat	B:pearl millet	C:finger millet	D:sorghum	E:chickpea	F:kulthi	G:rice bean	H:wheat	Starch	R.Starch	Amylose	GI
		g	g	g	g	g	g	g	G	%	%	%	%
14	1	0	0	0	0	1	-1	1	-1	26	2.54	2.54	37
19	2	-1	1	0	0	0	0	-1	1	27.5	2.83	3.09	40
49	3	-1	0	0	-1	0	-1	-1	0	26.34	2.75	3.12	39
70	4	1	-1	0	0	1	-1	0	0	23.98	2.65	3.23	38
34	5	-1	0	-1	0	0	1	0	1	26.23	2.6	2.45	36
89	6	0	-1	0	-1	0	-1	0	-1	25.99	2.55	2.12	40
78	7	0	0	1	-1	0	0	1	-1	26.34	2.54	1.97	29.43
42	8	0	-1	0	-1	1	0	1	0	27	2.57	2.65	37
18	9	-1	-1	0	0	0	0	1	1	24	2.67	2.45	39
63	10	0	1	1	0	-1	0	0	-1	23	2.98	2.9	37
59	11	0	-1	1	0	-1	0	0	1	25.87	3.2	2.87	39
66	12	-1	-1	0	0	1	1	0	0	23	3.04	2.45	38
79	13	0	0	1	1	0	0	-1	-1	24.54	3.01	2.76	37
109	14	0	1	-1	0	0	-1	1	0	27.34	2.99	2.56	38
98	15	-1	0	0	-1	1	0	0	1	26.55	2.96	2.34	38
95	16	0	1	0	1	0	-1	0	-1	25	2.45	2.98	36.04
74	17	0	0	-1	-1	0	0	1	1	24	2.56	2.56	41
10	18	0	0	0	0	-1	-1	1	1	23	2.98	2.45	40
52	19	-1	0	0	1	0	1	-1	0	28	2.34	2.97	35
5	20	1	-1	-1	1	0	0	0	0	32.27	2.56	2.99	37
118	21	0	0	0	0	0	0	0	0	25	2.76	3.01	42
72	22	1	1	0	0	1	1	0	0	30	2.45	3.04	38
77	23	0	0	1	-1	0	0	-1	1	30.33	2.87	3.2	39
64	24	0	1	1	0	1	0	0	1	25.45	2.9	2.98	38.23
97	25	-1	0	0	-1	-1	0	0	-1	26.87	2.45	2.54	36.87
22	26	1	-1	0	0	0	0	1	-1	26.98	2.65	2.55	32.23
91	27	0	-1	0	1	0	-1	0	1	25.44	2.22	2.6	38.92

56	28	1	0	0	1	0	1	1	0	26.98	2.6	2.65	32.12
83	29	-1	0	1	0	-1	0	1	0	27	2.45	2.75	30.12
6	30	1	-1	1	-1	0	0	0	0	26.45	3.23	2.97	31.58
27	31	0	0	-1	1	-1	1	0	0	25.98	2.54	2.57	32.12
53	32	1	0	0	-1	0	-1	1	0	25.87	3.09	2.54	33
48	33	0	1	0	1	1	0	1	0	27.34	3.06	2.75	34
110	34	0	1	-1	0	0	1	-1	0	31.36	3.05	2.65	45
75	35	0	0	-1	1	0	0	-1	1	28.94	3.02	2.34	35.7
60	36	0	-1	1	0	1	0	0	-1	26.34	2.57	3.08	37.82
20	37	-1	1	0	0	0	0	1	-1	27.32	3.33	3.12	29.03
32	38	0	0	1	1	1	1	0	0	26.34	2.45	2.76	32.95
99	39	-1	0	0	1	-1	0	0	1	25.45	2.95	2.87	34
111	40	0	1	1	0	0	-1	-1	0	26.34	2.76	2.98	45
94	41	0	1	0	-1	0	1	0	-1	27	2.88	2.99	32
1	42	-1	-1	-1	-1	0	0	0	0	23	2.95	2.35	24.21
104	43	1	0	0	1	1	0	0	1	24.98	2.45	3.23	44.09
90	44	0	-1	0	-1	0	1	0	1	26.32	2.66	3.23	31.34
9	45	0	0	0	0	-1	-1	-1	-1	26.12	2.76	2.98	46
62	46	0	1	-1	0	1	0	0	-1	28.23	2.87	2.87	32.94
39	47	1	0	1	0	0	-1	0	-1	29	2.43	2.67	28.94
4	48	-1	1	1	-1	0	0	0	0	30	2.22	2.55	27.56
84	49	-1	0	1	0	1	0	-1	0	22.34	2	3.4	35
96	50	0	1	0	1	0	1	0	1	29.55	3.23	3.02	38.02
54	51	1	0	0	-1	0	1	-1	0	23	3.02	2.87	38
33	52	-1	0	-1	0	0	-1	0	-1	22.45	3.01	2.67	34
112	53	0	1	1	0	0	1	1	0	26.45	2.99	2.09	29.04
115	54	0	0	0	0	0	0	0	0	28	2.97	2.9	33
65	55	-1	-1	0	0	-1	-1	0	0	29	2.98	2.78	35
67	56	-1	1	0	0	-1	1	0	0	24	2.87	2.87	36.76
44	57	0	-1	0	1	1	0	-1	0	26	2.76	2.44	35.23
25	58	0	0	-1	-1	-1	-1	0	0	27	3.12	2.56	33.76
116	59	0	0	0	0	0	0	0	0	24.69	3.08	2.76	42.34
40	60	1	0	1	0	0	1	0	1	30	3.03	2.45	37.41

73	61	0	0	-1	-1	0	0	-1	-1	34	3.01	2.45	34
87	62	1	0	1	0	-1	0	-1	0	32	3.64	2.76	35
38	63	1	0	-1	0	0	1	0	-1	33	2.77	2.77	36
55	64	1	0	0	1	0	-1	-1	0	34	2.86	2.59	37
61	65	0	1	-1	0	-1	0	0	1	35	2.35	2.65	42.5
24	66	1	1	0	0	0	0	1	1	31.26	2.88	2.66	43
103	67	1	0	0	1	-1	0	0	-1	30.48	2.97	2.34	32
46	68	0	1	0	-1	1	0	-1	0	26.76	2.45	2.55	34.56
17	69	-1	-1	0	0	0	0	-1	-1	27.34	2.34	2.98	35.45
106	70	0	-1	-1	0	0	1	1	0	26.34	3.23	2.66	32.45
80	71	0	0	1	1	0	0	1	1	26.98	2.87	2.87	30
7	72	1	1	-1	-1	0	0	0	0	28	2.67	2.76	34
45	73	0	1	0	-1	-1	0	1	0	28.4	2.55	2.54	36
120	74	0	0	0	0	0	0	0	0	32	2.67	2.33	34
100	75	-1	0	0	1	1	0	0	-1	30	2.87	2.75	38.23
8	76	1	1	1	1	0	0	0	0	27.26	2.56	2.55	32.34
93	77	0	1	0	-1	0	-1	0	1	24	2.45	2.1	34.21
29	78	0	0	1	-1	-1	1	0	0	28	2.98	2.09	33
69	79	1	-1	0	0	-1	1	0	0	21	3.17	2.08	37
82	80	-1	0	-1	0	1	0	1	0	25.45	3.52	2.45	38
30	81	0	0	1	-1	1	-1	0	0	29	2.13	2.33	32
43	82	0	-1	0	1	-1	0	1	0	27	1.98	2.13	31
11	83	0	0	0	0	-1	1	-1	1	33.23	2.73	2.46	36.08
117	84	0	0	0	0	0	0	0	0	31.02	1.78	3.45	34.56
101	85	1	0	0	-1	-1	0	0	1	30.04	3.23	2.73	32.34
85	86	1	0	-1	0	-1	0	1	0	29.45	2.48	3.12	33.54
88	87	1	0	1	0	1	0	1	0	28	2.87	2.67	31
102	88	1	0	0	-1	1	0	0	-1	25	2.56	2.97	34
36	89	-1	0	1	0	0	1	0	-1	24	2.45	2.34	36
23	90	1	1	0	0	0	0	-1	-1	29	2.76	2.67	38
26	91	0	0	-1	-1	1	1	0	0	34	2.98	2.87	37.45
86	92	1	0	-1	0	1	0	-1	0	33	2.78	2.88	35.67
21	93	1	-1	0	0	0	0	-1	1	32	2.67	2.67	36.23

76	94	0	0	-1	1	0	0	1	-1	29	2.9	2.54	35.67
105	95	0	-1	-1	0	0	-1	-1	0	28	3.12	2.33	31.5
3	96	-1	1	-1	1	0	0	0	0	27	3.24	2.99	39.54
13	97	0	0	0	0	1	-1	-1	1	26	2.34	2.88	40.03
57	98	0	-1	-1	0	-1	0	0	-1	24	2.45	2.34	41.35
114	99	0	0	0	0	0	0	0	0	23	2.65	2.37	39.23
35	100	-1	0	1	0	0	-1	0	1	22	2.7	2.97	36.05
41	101	0	-1	0	-1	-1	0	-1	0	32.39	2.75	2.48	35.92
119	102	0	0	0	0	0	0	0	0	38	2.55	2.98	36.01
50	103	-1	0	0	-1	0	1	1	0	32	2.85	2.04	38.23
51	104	-1	0	0	1	0	-1	1	0	28	2.56	3.12	37.23
113	105	0	0	0	0	0	0	0	0	26	2.96	3.11	40.41
47	106	0	1	0	1	-1	0	-1	0	32.58	3	2.38	38.23
15	107	0	0	0	0	1	1	-1	-1	27.83	2.76	2.96	39.12
37	108	1	0	-1	0	0	-1	0	1	32	2.77	3.02	38.21
31	109	0	0	1	1	-1	-1	0	0	30	2.96	3.22	36.23
107	110	0	-1	1	0	0	-1	1	0	26	2.33	3.02	37.04
71	111	1	1	0	0	-1	-1	0	0	29.53	2.45	2.99	39.45
2	112	-1	-1	1	1	0	0	0	0	28	2.33	2.87	37
68	113	-1	1	0	0	1	-1	0	0	23.46	2.45	2.78	37.344
16	114	0	0	0	0	1	1	1	1	24	2.49	2.98	45.35
28	115	0	0	-1	1	1	-1	0	0	27	2.34	2.78	39.45
92	116	0	-1	0	1	0	1	0	-1	24	2.33	2.34	37.21
58	117	0	-1	-1	0	1	0	0	1	26	2.67	2.54	36.23
81	118	-1	0	-1	0	-1	0	-1	0	32	2.15	2.78	37.23
108	119	0	-1	1	0	0	1	-1	0	23.02	3.24	2.98	38
12	120	0	0	0	0	-1	1	1	-1	19.74	2.94	2.5	36

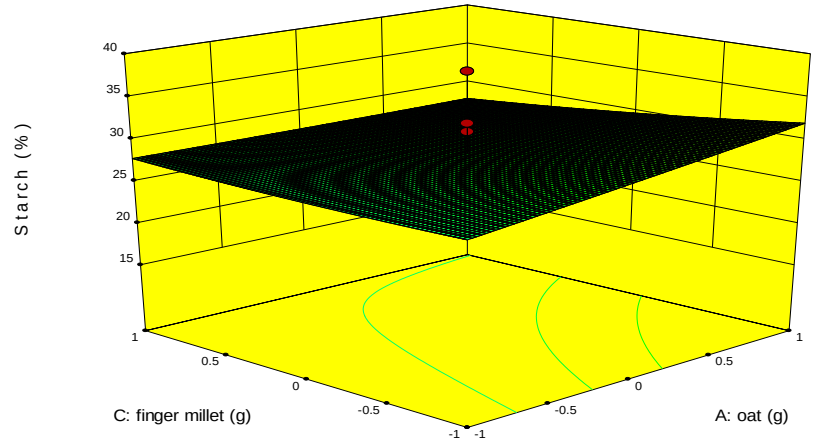
Table 4.32 Data analysis of kurkure

Parameters	Starch	Resistant Starch	Amylose	Glycemic Index
β_0	+28.46	+2.68	+2.86	+37.69
Oat –A	+1.18	+0.04	+0.01	-0.05
Pearl millet –B	+0.74	+0.03	+0.05	+0.45
Finger millet –C	-0.89	-0.04	+0.05	-0.78
Sorghum –D	+0.080	-0.03	+0.07	+0.64
Chick pea-E	-0.52	-0.06	+0.08	+0.38
Kulthi –F	+0.12	+0.07	-0.05	-0.44
rice bean –G	-1.01	-5.36	-0.08	-1.19
Wheat- H	+0.31	+0.02	+0.03	+1.08
A^2	+0.066	+0.03	+0.05	-1.28
B^2	-0.81	+0.01	-0.04	-0.23
C^2	+0.29	+0.07	-0.03	-1.64
D^2	+0.34	-0.02	-0.12	-1.97
E^2	-0.42	-0.02	-0.02	+0.45
F^2	-1.20	+6.12	-0.05	+0.57
G^2	+0.33	+0.06	-0.07	+0.11
H^2	-0.81	+6.12	-0.04	+0.79
AB	+0.35	-0.12	-0.12	-0.10
AC	-1.14	+0.17	-0.15	-0.89
AD	+1.33	-0.08	-0.11	-0.14
AE	-0.29	-0.14	+0.15	+0.37
AF	-0.87	+0.03	+0.02	+0.47
AG	-0.55	-0.13	+0.15	-0.43
AH	+0.86	-0.02	+0.08	+1.14
BC	-0.58	-3.12	-0.10	-2.33
BD	-0.19	+0.15	+0.11	+0.02
BE	-0.12	-0.02	-0.12	-0.81
BF	+1.05	+0.06	+0.04	+0.27
BG	+0.42	+0.09	+1.87	-1.66
BH	+0.89	+0.02	-0.10	+2.03
CD	-0.57	+0.05	+0.04	-0.94
CE	-0.17	-0.20	+0.04	-0.28
CF	-1.06	+0.06	-0.15	-0.71
CG	+1.08	-0.07	-0.20	-2.05
CH	+0.52	+0.13	+0.06	+0.17
DE	-0.30	-2.50	+0.04	+1.05
DF	-0.92	+0.06	-0.12	-1.09
DG	+0.18	-0.06	+0.14	-0.46
DH	-0.52	+0.02	+6.67	+0.26
EF	+1.28	+0.10	+0.14	+0.85
EG	+1.47	+0.08	-0.03	+1.33
EH	-1.72	-0.039	+0.04	+1.96
FG	+0.31	+0.043	+1.87	+0.09
FH	+0.61	-0.094	+0.05	-0.052
GH	-0.83	-0.023	+0.02	+1.79
R-Squared	0.5301	0.5112	0.6149	0.6323
Lack of fit (F-value)	*0.9990*	*0.9634*	*0.9862*	*0.8966*
Adequate precision	7.165	8.451	9.344	10.036

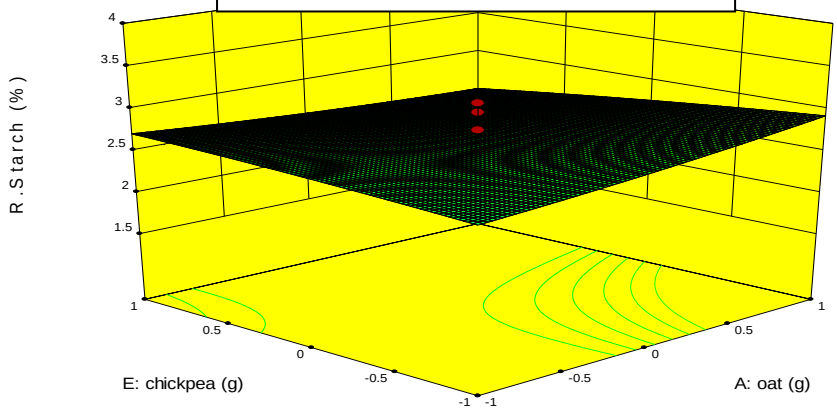
v. Data analysis of kurkure

The results for estimated coefficient of extruded products presented in Table 4.32. In fitted model for kurkure there were eight independent variables and four responses. The constant values were observed as 28.46, 2.68, 2.86, and 3.69 for responses starch, resistant starch, and amylose and glycemic index. The coefficient of determination ($R^{2)}$ was observed 0.53, 0.51, 0.61, and 0.63 for variables starch, resistant starch, and amylose and glycemic index. The lack of fit values were non significant for all the variables and adequate precision values were found 7.16, 8.45, 9.34, 10.04 for resposes starch, resistant starch, amylose and glycemic index respectively. In regression analysis of response starch, variable A showed a significant ($p \leq 0.001$) positive linear effect while C had a significant ($p \leq 0.001$) negative linear effect. The quadratic coefficient of variables B, F and H had significant ($p \leq 0.05$) negative quadratic effect on response starch. In combination of variables, AC and EH showed a significant ($p \leq 0.05$) negative effect and AD, EF and EG had a significant ($p \leq 0.05$) positive effect on starch content. For response resistant starch variable G displayed a very significant ($p \leq 0.001$) negative linear effect, whereas the quadratic coefficient of variable F displayed a very significant ($p \leq 0.05$) positive quadratic effect. In interaction of variables, BC and DE showed a very significant ($p \leq 0.05$) negative effect while AC and CH had a significant ($p \leq 0.05$) positive effect. In case of response amylose all the variables showed significant ($p \leq 0.001$) positive linear effect expect variables F and G. The quardratic coefficient of all the variables had a significant ($p \leq 0.05$) negative quadratic effect expect variable A. In combination of variables, BG, DH and FG had a very significant ($p \leq 0.05$) positive effect. For response Glycemic index variable G displayed a significant ($p \leq 0.001$) negative linear effect while H had a significant ($p \leq 0.001$) positive linear effect. The quadratic coefficient of variables A, C and D had a significant ($p \leq 0.05$) negative correlation. However in case of the interaction of variable BC and CG showed a very significant ($p \leq 0.05$) negative whereas EG and EH had very significant ($p \leq 0.05$) positive effect on response glycemic index. The response surface plot as shown in Figure (4.8)

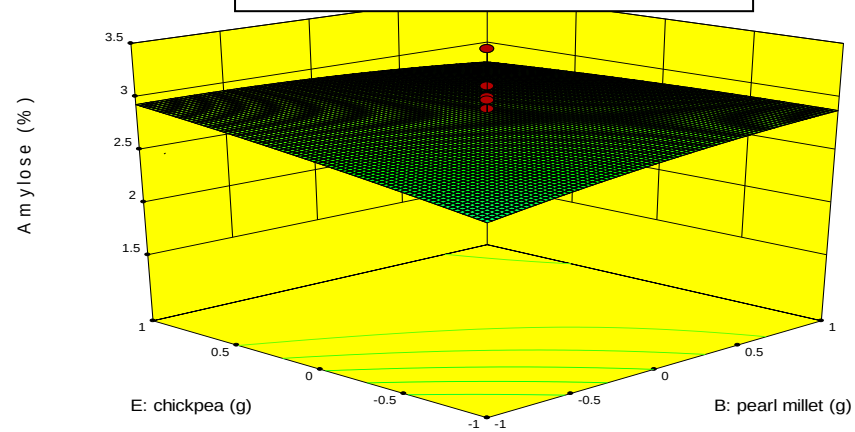
The response surface plots for Kurkure



1. A (Oat) : C (Finger millet)



2. A (Oat) : E (Chick pea)



3. B (Pearl millet) : E (Chick pea)

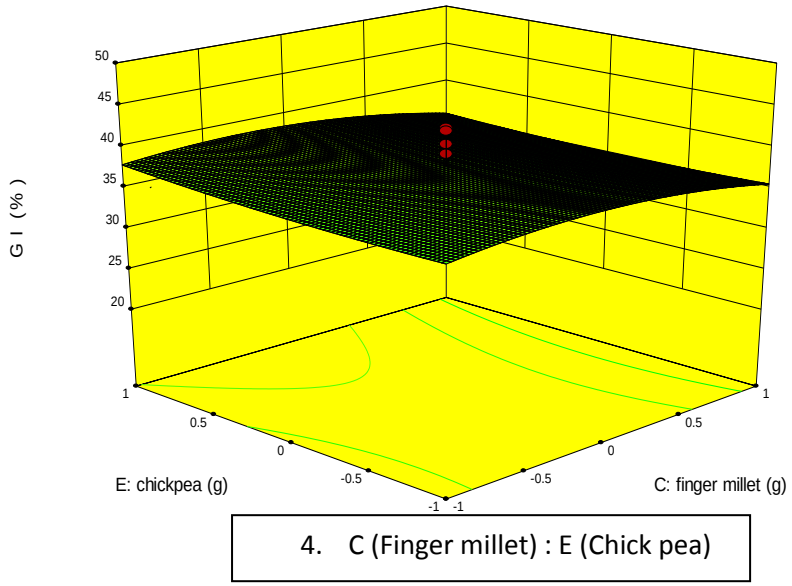


Figure 4.8: Response surface plots for kurkure

vi. Figure 4.8 reveals surface plot for responses starch, resistant starch, and amylose and glycemic index respectively. For response starch (Plot.1) it is observed that with the increase of oat and pearl millet there is increase in starch content and increase is more significant with oat. In case of resistant starch (Plot.2) with the increase in oat and chick pea there is increase in resistant starch but the increase is more significant in case of oat. Plot.3 reveals that with the increase in pearl millet and chick pea increase in amylose content but the effect is non significant. In sace of glycemic index with the increase of pearl millet there is significant decrease in glycemic index.

4.2.5 Optimization

The optimum condition for the development of products was determined by using the following criteria by Design Expert Software 9. According to which the product should get the maximum fiber and resistant starch content, minimum fat, protein, moisture content. The products should be selected for ash starch and amylose content in range. After numerical optimization design expert gives solution for optimized formulation. The optimized formulations for all products is presented in the pertinent tables.

Table 4.33 Optimized composition of bread (g)

Wheat	**Oat**	**Finger millet**	**Pearl millet**	**Sorghum**
10.00	35 .00	27.00	13.00	15.00

Table 4.34 Optimized composition of soup sticks (g)

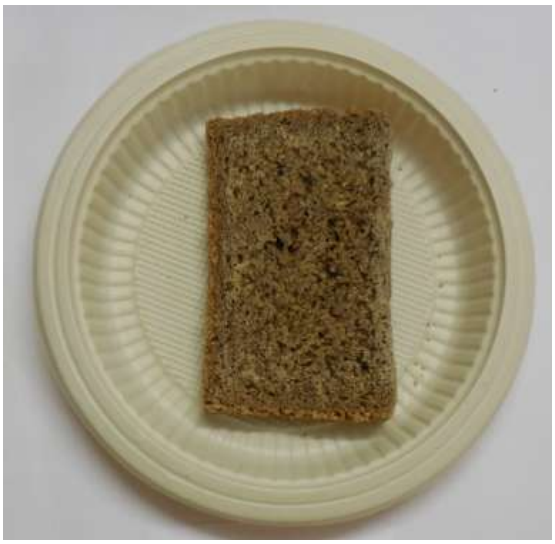
Wheat	Chick pea	Rice bean	Horse gram
10.00	42 .00	27.00	13 .00

Table 4.35 Optimized composition of rusk (g)

Wheat	Oat	Finger millet	Pearl millet	Sorghum
10 .00	36.00	33.00	7.00	14.00

Table 4.36 Optimized composition of kurkure (g)

Wheat	Oat	Finger millet	Pearl millet	Sorghum	Chick pea	Rice bean	Horse gram
9.00	21.00	17.00	4.00	16.00	18.00	3.00	15.00



1. Bread

2. Soup sticks

3. Rusk

4. Kurkure

Plate 4.8: Value added products

4.3 Physiochemical, functional and quality assessment of developed food matrix

Evaluation of value added products

The prepared products were evaluated in terms of objective as well as subjective parameters. The results thus obtained presented in pertinent tables. Earlier, Chandera et al. (2018) also made an attempt to develop enriched multi grain bread with wheat flour, gram flour, ragi and soya. Sattar et al. (2018) also formulated the bread sticks with germinated and non germinated legumes, Nazni and karuna (2016) developed seven formulations of millet bran rusk and Reddy et al. (2014) developed the extruded *Ready-to-Eat* (RTE) snacks by using corn, black gram, roots and tuber flour blends. The results are presented as follows :-

4.3.1 Proximate evaluation of freshly prepared products

The data in Table 4.37 reflects the experimental values for prepared products *viz*, bread, soup sticks, rusk and kurkure respectively. As it is evident from same table the values for different proximate components are described below:

1) **Moisture**

   As it evident from Table 4.37 the value for moisture content in case of different products was observed to be 30.30, 4.11, 3.90, 2.61 per cent case of bread, soup sticks, rusk and kurkure respectively.

2) **Ash**

   Same table depicts the ash per cent of prepared products was found as 4.23, 4.32, 4.72 and 6.12 in case of bread, soup sticks, rusk and kurkure respectively.

3) **Crude Fat**

   It is clear from Table 4.37 that the per cent values for crude fat content of bread, soup sticks, rusk and kurkure were observed as 6.42, 0.44, 6.84, 0.23, per cent respectively.

4) **Crude Fiber**

   Crude fiber content of the prepared products can be observed form Table 4.37 as 0.29, 0.21, 0.22, 0.29 per cent in bread, soup sticks, rusk, kurkure respectively.

5) Crude Protein

From the presual of same table the values for crude protein were observed to be 3.30, 6.10, 6.90 and 3.27 per cent for bread, soup stick, rusk and kurkure respectively.

Table 4.37 Proximate composition of freshly prepared products (per cent)

Products / Parameters	Bread	Soup Stick	Rusk	Kurkure
Moisture	30.30±0.02	4.11±0.02	3.90±0.04	2.61±0.02
Ash	4.23±0.02	4.32±0.02	4.72±0.056	6.12±0.02
Crude Fat	6.42±0.02	0.44±0.02	6.84±0.04	0.23±0.03
Crude Fiber	0.29±0.02	0.21±0.02	0.22±0.02	0.29±0.02
Crude Protein	3.30±0.03	6.10±0.02	6.90±0.04	3.27±0.04

4.3.2 Mineral evaluation for freshly prepared products

Table 4.38 depicts the data for minerals evaluation of freshly prepared bread, soup sticks, rusk and kurkure. The values of minerals like potassium, calcium and magnesium were found to be highest as 46.00, 49.36, and 21.56 mg/100g respectively in bread sample whereas, iron and zinc were found highest in rusk as 4.71 and 2.21mg/100g respectively. Sodium content was found maximum in soup sicks having concentration of 288.00 mg/100g. Sodium, potassium and calcium were found to be lowest in kurkure as 88.00, 17.00, and 12.00 mg/100g respectively, whereas iron and zinc were found to be minimum in bread as 2.51 and 0.90 mg/100g. Magnesium was found highest in soup sticks. Earlier, Juhaimi et al. (2015) also studied the mineral content of traditional breads enriched with floral honey. Sattar et al. 2018 studied the mineral content of soup sticks, Chaturvedi and Rawat (2018) studied the mineral composition of barnyard millet flour based rusk. Anuonye et al. (2012) studied the mineral composition of extruded product developed from pigeon pea and unripe plantain blends.

Table 4.38 Minerals evaluation of freshly prepared products (mg/100g)

Products / Parameters	Bread	Soup sticks	Rusk	Kurkure
Na	244±7.78	288±4.96	190±1.47	88±2.94
K	46.0±3.55	26.0±2.16	36.0±2.94	17.0±2.16
Ca	49.36±0.95	18.14±1.87	16.46±1.48	12.22±2.12
Mg	21.56±2.70	4.52±0.91	11.45±1.29	3.46±1.29
Fe	2.51±0.25	2.96±0.38	4.71±0.65	3.71±0.73
Zn	0.9±0.04	1.05±0.16	2.21±0.49	1.91±0.57

4.3.3 Sugars, starches and glycemic index evaluation of freshly prepared products

Carbohydrates are crystalline in structure, sweet to taste and dissolve easily in water. It is a macronutrient and main source of energy for the body. The word carbohydrate refers to the wide range of sugars and starches found in different foods. Earlier, Sharmila and Athmaselvi (2017) also studied the nutritional composition of extruded snacks prepared from blends of under- utilized legumes and millets.

1) Starch

A glance at Table 4.39 reveals that per cent starch content in products ranged from 18.71 to 36.54 per cent in supsticks and bread respectively, whereas, the rest of the values were found in the intermediate range.

2) **Resistant Starch**

From the perusal of same table the values for resistant starch were observed to be 4.52, 2.64, 3.59 and 2.54 per cent for bread, sup sticks, rusk and kukure respectively.

3) Amylose

On the day of processing the amylose content of prepared four products were found to be 10.54, 7.39, 8.51, and 2.54 per cent for bread, soup sticks, rusk and kurkure respectively.

4) Glycemic Index

Glycemic index of the prepared products was found to be in the range of 24.50 to 52.00 The lowest glycemic index was found for soup sticks and the highest value was found for bread. The other values are obtained in the intermediate range for rusk and kurkure. But both the values lowest and highest comes under the range of low glycemic indexed food.

5) Sugars

Table 4.39 depicts that total sugar ranged from 0.26 to 14.02 and rest of the values obtained in the intermediate range. Reducing sugars ranged from 0.09 to 6.15 whereas, the values for non reducing sugars were observed as 1.58, 7.90, 0.18 and 7.64 for bread, sup sticks, rusk and kurkure respectively.

Table 4.39 Sugars, starch and glycemic index evaluation of freshly prepared products (per cent)

Products / Parameters	Bread	Soup sticks	Rusk	Kurkure
Total Sugar	2.78±4.00	14.02±4.00	0.26±1.29	10.05±0.29
Reducing Sugar	1.23±0.40	6.15±0.40	0.09±0.72	2.44±0.07
Non- Reducing	1.58±1.67	7.90±0.67	0.18±0.60	7.64±0.02
Starch	36.54±2.12	18.71±1.32	28.52±1.24	26.0±2.16
ResistantStarch	4.52±0.53	2.64±0.52	3.59±1.61	2.54±0.83
Amylose	10.45±1.27	7.39±0.61	8.51±1.55	2.54±0.83
Glycemic Index	52.00±2.16	24.50±2.18	36.00±1.33	37.00±3.55

4.3.4 Texture analysis of freshly prepared products

Texture is defined as those properties of a food that sensed by touch by the means of mouth feel and with hand. Texture analysis was carried out by an electronic sensing system that represent a range of textures. Efforts were made to study the textural profile in 2017 by Agarwqal et al. in multigrain bread developed by using

wheat, buckwheat and pearl millet flour. Earlier, Rehman et al.(2013) analyzed the texture profile of rusk while studying the biotechnological production of xylitol from banana peel and its impact on physico-chemical properties of rusk.

Hardness

Hardness of freshly prepared products was observed as 3.70, 23.00, 63.50 and 3.40 for bread, sup sticks, rusk and kurkure respectively.

Fructurability

A glance at plate 4.9 reveals that fracturability of freshly prepared products as 2.20N, 11.60N, 43.30N, and 1.40 N for bread, soup sticks, rusk and kurkure respectively.

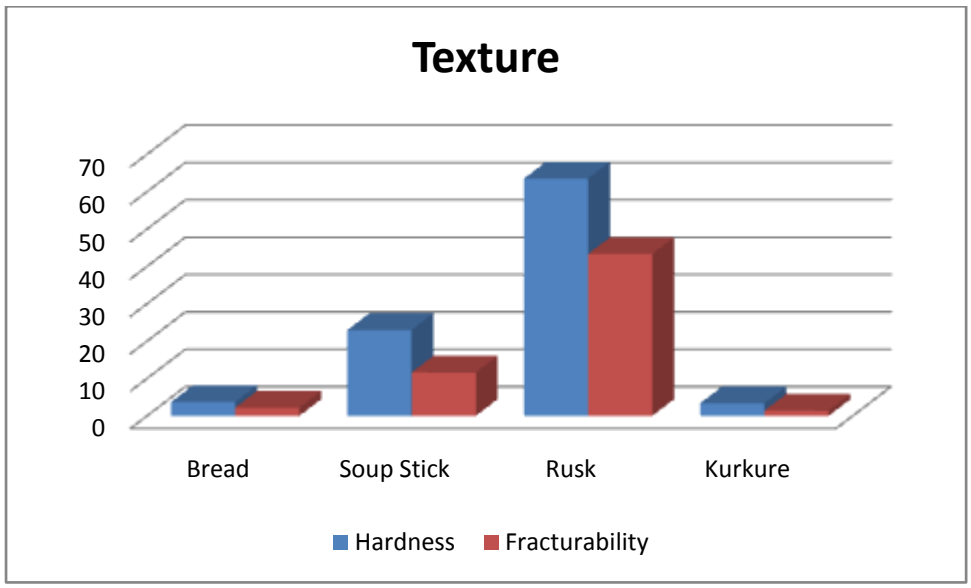


Plate 4.9: Texture evaluation of freshly prepared products (N)

4.3.5 Organolaptic evaluation of freshly prepared products

Table 4.40 illustrates the organolaptic scores for freshly prepared products. As is evident from the table, consumers preferred bread in comparison to other products on the basis of colour. As far as flavour is concerned, consumers preferred equally bread, soup sticks and kukure as they have given 7.00 score to all the products, but liked least rusk with a score value of 5.70. Kurkure scored maximum value (6.90) for taste as bread, soup sticks got equal score (6.50) and rusk got minimum score of value 5.60. On the basis of texture, the preference trend was observed same as kurkure,

bread, rusk and soup sticks. Overall consumers like kurkure (7.25) followed by bread (7.20), soup sticks (6.75) and rusk (6.25) respectively.

The organoleptic evaluation was also done by Agarwal et al. (2017) in multigrain bread prepared by using wheat, buck wheat and pearl millet flour and found it acceptable. Earlier in 2011, Desdpande and Poshdri also studied the physical and sensory characteristics of extruded snacks prepared from foxtail millet based composite flours.

Table 4.40 Organolaptic evaluation of freshly prepared products

	Bread	**Soup sticks**	**Rusk**	**Kurkure**
Colour	7.70±0.67	6.50±1.08	6.20±1.03	7.00±1.05
Flavour	7.00±0.81	7.00±0.94	5.70±1.25	7.00±0.81
Taste	6.50±1.08	6.50±1.08	5.60±1.07	6.90±0.87
texture	7.50±1.17	7.00±1.05	7.50±1.17	8.10±0.87
Overall Acceptability	7.20±0.56	6.75±0.54	6.25±0.48	7.25±0.40

4.4 Assessment of sensory and shelf stability of developed products

Evaluation of products during storage

The prepared food products samples were kept for storage at ambient temperature to see the shelf stability. They were analyzed after an interval of 30 days for up to 4 months. The data with regard to different products stored on processing day and various storage intervals are shown in their pertinent tables. The results are discussed as follows:

4.4.1 Effect of Storage intervals on proximate composition of developed products

i. Soup Sticks

As it is evident from table 4.41 of soup sticks the values for moisture content 4.11, 4.14, 4.32, 4.58 and 4.64 per cent for 0, 30, 60, 90 and 120 days which shows that moisture increased significanltly with increasing duration of storage. The increase in moisture content might be due to hygroscopic nature of material which absorb the moisture content from atmosphere. Same table reveals that there was overall non significant increase in ash per cent in case of soup sticks and the increase between the 30-60 days, 60-90 days and 90-120 days i.e. 5.64-5.67, 5.67-5.68 and 5.68-5.71 per cent were also non significant. The increase in ash content might be due to some of

the chemical changes during storage which increase the total mineral content. In soup sticks the overall decrease in fat content was non significant, and the difference between the regular intervals i.e. 0, 30, 60, 90 and 120 days was also found not significant. The non significant decrease in fat content might be due to the per-oxidation of fat. Similarly, the storage effect on soup sticks showed that fiber content decreased non significantly with the increasing storage. But in totality it decreased significantly up to a span of 120 days. The difference between the 0-120 days i.e. 0.21- 0.17 per cent was significantly decreased. This decrease in fiber content might be due to the degradation of the lignin, cellulose and semi-cellulose content of fiber. In soup sticks there is decrease in the crude protein content during storage, overall decrease in protein was also non significant and the difference between the storage intervals were also non significant as the values for 0, 30, 60, 90 and 120 days of storage interval i.e. 6.10, 6.09, 6.09, 6.06 and 6.05 per cent respectively.

4.41 Effect of storage intervals on proximate composition of soup sticks

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Moisture (%)	4.11±0.02	4.14±0.01	4.32±0.01	4.58±0.02	4.64±0.02
Ash (%)	5.64±0.02	5.64±0.02	5.67±0.02	5.68±0.02	5.71±0.02
Crude Fat (%)	6.44±0.02	6.44±0.03	6.42±0.02	6.42±040	6.41±0.01
Crude Fiber (%)	0.21±0.02	0.21±0.03	0.20±0.03	0.19±0.02	0.17±0.02
Crude Protein (%)	6.10±0.01	6.09±0.04	6.09±0.04	6.06±0.05	6.05±0.00

ii. Rusk

It is clear from Table 4.42 that moisture content increased significantly in rusk. However, the increase up to 80 days of storage moisture content increased non significantly. Thereafter, up to 120 days the increase was significant. The difference between 90 to 120 days i.e. 4.23 – 4.29 per cent was found non significant. The increase in moisture content might be due to porous nature of material which absorbs the moisture content from atmosphere. Same table shows the non significant increase in ash content and the difference between the intervals of analysis was also non significant. This increase in ash content might be due to some changes in total mineral

content during storage. The storage effects on fat content of rusk was non significant, between the regular storage intervals whereas, the difference between the 0-120 days i.e. 5.84-5.78 per cent was found to be significant. The non significant decrease in fat content might be due the degradation of the lipid bonds. Same trend was observed in the storage of rusk. Overall non significant decrease in crude fiber was observed between the storage interval of 0-30 days but after a span of 30 days till the end of 120 days it decrease significantly. i.e. 0.22-0.16 per cent respectively. This decrease in fiber content might be due to the degradation of the lignin, cellulose and semi-cellulose content of fiber. Same trend was found in the rusk, overall effect on crude protein content was found to be non significant within the regular storage intervals with values 6.90, 6.88, 6.87, 6.87 and 6.86 per cent respectively for 0-120 days.

Table 4.42 Effect of storage intervals on proximate composition of rusk

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Moisture (%)	3.90±0.04	3.92±0.04	4.14±0.06	4.23±0.06	4.29±0.43
Ash (%)	4.72±0.06	4.74±0.07	4.74±0.07	4.77±0.08	4.79±0.08
Crude Fat (%)	5.84±0.04	5.84±0.04	5.81±0.03	5.80±0.03	5.78±0.03
Crude Fiber (%)	0.22±0.02	0.22±0.02	0.20±0.04	0.19±0.03	0.16±0.04
Crude Protein (%)	6.90±0.04	6.88±0.04	6.87±0.04	6.87±0.04	6.86±0.04

iii. Kurkure

On thorough study of Table 4.43 it was found that in case of kurkure, moisture increased non significantly during storage i.e. 0, 30, 60, 90, 120 days. This might be due to hygroscopic nature of material coupled with porosity of food material which absorbs the moisture content from atmosphere. Same table also reveals ash content also decreased non significantly. This non significant increase might be due to some of the chemical changes during storage. The decrease in fat content was non significant and also difference between all the storage intervals was non significant. This might be due to the per-oxidation of fat during storage period. The same trend was observed for crude fiber during the storage. The overall decrease in crude fiber

content during storage intervals was non significant. This might be due to the degradation of the lignin and cellulose content during storage. Similarly protein content was decreased significantly, the difference between 0-120 and 30-120 days was also significant with the values 3.27-3.20 and 3.26-3.20 per cent respectively. But the difference between the regular intervals was non significant. The significant decrease in protein content might be due to the denaturation of proteins coupled with the inactivity of enzyme during the storage study. Balfour et al. (2014) also studied the self stability of extruded fortified snack and obtained that there was slight decline in the proximate composition of the snack during storage study of 60 days.

Table4.43 Effect of storage intervals on proximate composition of kurkure (per cent)

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Moisture (%)	2.61±0.02	2.61±0.03	2.65±0.02	2.68±0.04	2.70±0.06
Ash (%)	6.12±0.02	6.12±0.02	6.13±0.04	6.15±0.05	6.16±0.05
Crude Fat (%)	3.23±0.03	3.23±0.03	3.23±0.03	3.21±0.03	3.20±0.03
Crude Fiber (%)	0.29±0.02	0.28±0.02	0.26±0.01	0.26±0.03	0.22±0.03
Crude Protein (%)	3.27±0.04	3.26±0.02	3.24±0.02	3.24±0.02	3.20±0.02

4.4.2. Effect of storage study on the minerals content of prepared products

An attempt was made to study the effect of storage on the mineral content of the prepared products and the results are presented in pertinent tables.

i. Soup Sticks

On thorough study of Table 4.44 it is observed that in soup sticks overall non significant decrease was recrded in sodium and the difference between the regular intervals also also varied non significantly with the values 288, 288, 286, 284, 284mg/100g for 0, 30, 60, 90 and 120 days respectively. In soup sticks the increase in potassium contents was found to be non significant and between the regular intervals of storage period with the values varied 26.00, 26.02, 26.05, 26.05, 26.05mg/100g for 0, 30, 60, 90 and 120 days of storage respectively. Similarly, the Mg content in soup

sticks decreased during the storage period but the decrease was not significant with the values 4.52, 4.52, 4.49, 4.48, 4.48 mg/100g for 0, 30, 60, 90 and 120 days of storage respectively. Iron content of soup sticks non significantly and between the storage intervals i.e. 0, 30, 60, 90, 120days values as 2.96, 2.98, 2.98, 3.01, 3.02 mg/100g respectively. For soup sticks the Zn content decreased non significantly and within the regular intervals of storage as 1.05, 1.05, 1.01, 0.98, 0.98 for 0, 30, 60, 90 and 120 days of storage respectively.

The larger the portion of the grain removed, the greater is the nutrients loss. When wheat is milled into wheat flour, there is an approximate 70% loss of vitamins and minerals (range 25–90%) and fiber, 25% loss of protein, 90% loss of manganese, 85% loss of zinc and linoleic acid, and 80% loss of magnesium, potassium, copper, and vitamin B6 (Ramberg and McAnalley, 2002; Redy and Love, 1999). Refining decreases the contents of almost all nutrients in wheat flour. As observed by Oghbaei and Prakash (2013) refining decreased protein, fat, ash, calcium, iron, and zinc in wheat flour. As the outer parts of the kernel, especially the aleurone layer and the germ, are richer in minerals when compared to the starchy endosperm, conventional milling reduces their content in flour and concentrates them in the milling residues. Differences in the mineral content is likely to exist even between the outer endosperm and the inner endosperm (Brondi et al. 1984). The grain shape and texture and the technical conditions of milling, principally the extraction rate, are important in determining the extent of mineral loss.

Table 4.44 Effect of storage intervals on minerals composition of soup sticks

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Na (mg/100g)	288.00±4.96	288.00±4.96	286.00±2.16	284.00±2.94	284.00±2.94
K (mg/100g)	26.00±2.16	26.02±1.40	26.05±1.39	26.05±1.39	26.05±1.39
Ca (mg/100g)	18.14±1.87	18.14±1.87	18.19±1.41	18.21±1.48	18.25±3.55
Mg (mg/100g)	4.52±0.91	4.52±0.91	4.49±1.77	4.48±1.75	4.48±1.75
Fe (mg/100g)	2.96±0.38	2.98±0.33	2.98±0.33	3.01±0.82	3.02±0.81
Zn (mg/100g)	1.05±0.16	1.05±0.16	1.01±0.02	0.98±0.11	0.98±0.11

ii. Rusk

On critical look of Table 4.45 it was observed that in rusk the overall decrease in sodium content was non significant and the difference between the regular intervals of storage were also non significant depicting values as 190, 189, 186, 186, 184 mg/100g for 0, 30, 60, 90 and 120 days respectively. Same trend was observed in case of potassium where the increase was non significant between the regular interval of storage with the values as 36.00, 36.00, 36.03, 36.07, 36.10mg/100g for 0, 30, 60, 90 and 120 days of storage. The data values for calcium in rusk during storage were observed as 16.46, 16.46, 16.46, 16.46 and 16.49mg/100g for 0, 30, 60, 90 and 120 days storage respectively which follow the same trend as potassium. Which might be due to the hydrolysis of the Ca from pectate bonds of the cell walls. The Mg content of rusk during the storage period decrease non significantly between the regular intervals of storage period with values 11.45, 11.45, 11.42, 11.42, 11.40 mg/100g observed for 0, 30, 60, 90 and 120 days of storage interval. Iron content of rusk also increased non significantly between the storage intervals of 0, 30, 60, 90, 120 days depicting values as 4.71, 4.71, 4.74, 4.78 and 4.80mg/100g respectively. In rusk, Zn content decreased non significantly within the regular intervals of storage with the values as 2.21, 2.18, 2.14, 2.12, 2.10mg/100g for 0, 30, 60, 90 and 120 days of storage respectively. Differences in the mineral content is likely to exist even between the outer endosperm and the inner endosperm (Brondi et al. 1984). The grain shape and texture and the technical conditions of milling, principally the extraction rate, are important in determining the extent of mineral loss.

Table 4.45 Effect of storage intervals on minerals composition of rusk

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Na (mg/100g)	190.00±1.47	189.00±4.32	186.00±2.16	186.00±2.16	184.00±2.94
K (mg/100g)	36.00±2.94	36.00±2.94	36.03±2.91	36.07±2.91	36.10±3.63
Ca (mg/100g)	16.46±1.48	16.46±1.48	16.46±1.48	16.46±1.48	16.49±1.51
Mg (mg/100g)	11.45±1.29	11.45±1.29	11.42±0.82	11.42±0.82	11.40±.05
Fe (mg/100g)	4.71±0.65	4.71±0.65	4.74±0.72	4.78±0.98	4.80±0.83
Zn (mg/100g)	2.21±0.49	2.18±0.44	2.14±0.34	2.12±0.32	2.10±0.25

iii. Kurkure

In storage study of minerals in kurkure, a closer look on Table 4.46 reveals that unlike in other products sodium content decreased significantly but the difference between the regular intervals of storage was non significant. On the perusal of same table, it was observed that in kurkure there was a overall non significant increase in potassium and also between the regular storage intervals with the values 17.00, 17.00, 17.05, 17.09, 17.14 for 0, 30, 60, 90 and 120 days of storage intervals respectively. The data for calcium during storage period was found as 12.22, 12.22, 12.26, 12.29, 12.33mg/100g for 0, 30, 60, 90 and 120 days of storage intervals respectively. On the other hand, Mg decreased non significantly and the difference between the regular period of storage interval was also non significant. Iron content of kurkure increased non significantly between the storage intervals of 0, 30, 60, 90, 120 days with the values as 3.71, 3.71, 3.75, 3.77, 3.79mg/100g respectively. In kurkure there is decrease in overall Zn content and the decrease was also non significant between the regular time interval of storage with the values 1.91, 1.91, 1.88, 1.84, 1.82 for 0, 30, 60, 90 and 120 days respectively. As observed by Oghbaei and Prakash (2013) refining decreased protein, fat, ash, calcium, iron, and zinc in wheat flour. As the outer parts of the kernel, especially the aleurone layer and the germ, are richer in minerals when compared to the starchy endosperm, conventional milling reduces their content in flour and concentrates them in the milling residues.

Table 4.46 Effect of storage intervals on minerals composition of kurkure

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Na (mg/100g)	88.00±2.94	88.00±2.94	88.00±2.94	86.00±1.63	83.00±2.16
K (mg/100g)	17.00±2.16	17.00±2.16	17.05±2.20	17.09±1.73	17.14±1.23
Ca (mg/100g)	12.22±2.12	12.22±2.12	12.26±1.19	12.29±0.91	12.33±0.47
Mg (mg/100g)	3.46±1.29	3.46±1.29	3.45±1.35	3.42±1.32	3.38±1.32
Fe (mg/100g)	3.71±0.73	3.71±1.00	3.75±0.92	3.77±0.91	3.79±0.90
Zn (mg/100g)	1.91±0.67	1.91±0.67	1.88±0.67	1.84±0.68	1.82±0.66

4.4.3 Effect of storage interval on starch content of prepared products

i. Soup sticks

The data presented in Table 4.47 present the effect of storage intervals on starch composition in soup sticks. As is evident form the table, that value for starch In storage study of soup sticks, the increase in starch content was also non significant during the storage period. The starch content during the storage period of time increase non significantly which might be due to the change in starch molecule structure during the processing. Starch molecules reassociate to generate a new crystalline order which improves the availability. Similarly in soup stick there was overall non significant decrease in resistant starch, the decrease between the regular time interval of storage was also non significant as the values for data were observed as 2.64, 2.64, 2.61, 2.58, 2.57mg/100g for 0, 30, 60, 90 and 120 days of storage. This might be due to the decrease in total crude fiber during the storage study. For the soup sticks the values of amylose were reported as 7.39, 7.39, 7.33, 7.29 and 7.27mg/100g for 0, 30, 60, 90 and 120 days of storage respectively. There was non significant decrease in amylose content between the storage intervals which might be due to degradation of starch during the storage period of time. In suop sticks the value for glycemic index were observed as 24.50, 24.50, 24.54, 24.57, 24.60 for 0, 30, 60, 90 and 120 days of storage period respectively. There was non significant increase in glycemic index during the storage period and between the regular intervals of storage. This might be due to the change in sugar content during the storage study.

Table 4.47 Effect of storage intervals on starch composition in soup sticks

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Starch (%)	18.71±1.32	18.71±1.32	18.74±0.67	18.75±0.70	18.77±0.90
ResistantStarch (%)	2.64±0.52	2.64±0.52	2.61±0.52	2.58±0.53	2.57±0.51
Amylose (%)	7.39±0.61	7.39±0.61	7.33±0.58	7.29±0.58	7.27±0.52
Glycemic Index	24.50±2.18	24.50±2.18	24.54±2.51	24.57±1.71	24.60±0.84

ii. Rusk

On thorough study of Table 4.48 it was observed as the data on the initial day was 28.52 which was finally increased to 28.59 per cent after a period of 120 days increased non significantly with the increasing storage intervals. This might be due to the degradation of polysaccharide into simple sugar and starch. Similar trend was observed in rusk for resistant starch, which was decreased non significantly with the incremental increase in storage period. This decrease might be due to the modification as of starch. The initial value for amylose content was 8.51 per cent which was decreased to 8.41 per cent after a period of 120 days. Glycemic index on the day of processing was calculated as 36.00 which was non signiginantly increased during the storage. This might be due to degradation of starch content during the storage period.

Table 4.48 Effect of storage intervals on starch composition of rusk

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Starch %	28.52±1.24	28.52±1.24	28.52±1.24	28.55±1.17	28.59±1.28
ResistantStarch %	3.59±1.61	3.59±1.61	3.55±0.95	3.53±0.92	3.53±0.92
Amylose %	8.51±1.55	8.51±1.55	8.46±0.83	8.43±0.53	8.41±0.51
Glycemic Index	36.00±1.33	36.00±1.33	36.16±0.76	36.24±4.44	36.29±4.46

iii. Kurkure

It was attempted to see the effect of storage on starch, resistant starch, amylose and glycemic index in kurkure and the results obtained were presented in Table 4.49. A glance at the same table reveals that initial value which was 26.00 per cent hardly increased to 26.06 per cent after 120 days. On the other hand, a slight decrease was observed in case of resistant stach and amylose as evident from data from the same table. Though the decrease was non significant this might be due to degradation of starch during storage. The value for glycemic index was observed to be 37.00, 37.00, 37.08, 37.13 and finally 37.19 during 0, 30, 60, 90 and 120 days of storage. This non significant increase might be due to some chemical changes in the sugar composition during the storage period.

In kurkure the increase of starch content was non significant during the storage period and the increase during the regular interval of storage period was also found

non significant with the values as 26.00, 26.00, 26.00, 26.02 per cent starch during 0, 30, 60, 90, 120 days of storage intervals respectively. This might be due to the degradation of starch during which the molecules reassociate to generate a new crystalline order which improves the availability. Similar trend was observed in kurkure resistant starch where there was overall decrease in resistant starch during storage was also non significant for regular interval of storage period. The values for resistant starch are observed as 2.54, 2.54, 2.51, 2.48, 2.45 for the time period of 0, 30, 60, 90 and 120 days of storage respectively. Amylose content of the kurkure was observed with the values of 2.54, 2.54, 2.52, 2.50, 2.47 per cent for time period 0, 30, 60, 90 and 120 days of storage respectively might be due to degradation of starch. In kurkure the value for glycemic index observed as 37.00, 37.00, 37.08, 37.13, 37.19 for 0, 30, 60, 90 and 120 days of storage period respectively. There was non significant increase in overall storage period and between the regular storage intervals. This might be due the some chemical changes in the sugar composition during the storage period.

Table 4.49 Effect of storage intervals on starch composition of kurkure

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Starch (%)	26.00±2.16	26.00±2.16	26.00±2.16	26.02±2.68	26.06±3.17
Resistant Starch (%)	2.54±0.83	2.54±0.83	2.51±1.07	2.48±0.59	2.45±0.57
Amylose (%)	2.54±0.83	2.54±0.83	2.52±0.91	2.50±0.98	2.47±0.80
Glycemic Index	37.00±3.55	37.00±3.55	37.08±2.85	37.13±3.56	37.19±2.16

4.4.4 Effect of storage on reducing, non reducing and total sugar on value added products

i. Effect of storage on reducing, non reducing and total sugar composition of rusk

Table 4.50 reveals that reducing sugars increased non significantly with the increased duration of storage in rusk and the values were observed as 6.15, 6.16, 6.20, 6.20 and 6.26 per cent for 0, 30, 60, 90, and 120 days respectively. This increase in reducing sugars might be due to the hydrolysis of sucrose to glucose and

fructose. During the storage period the non reducing sugars also decrease non significantly between the storage intervals with the values as 7.90, 7.89, 7.84, 7.84, 7.81 per cent for 0, 30, 60, 90 and 120 days of storage respectively this might be due to the hydrolysis of non reducing sugars to reducing sugars during the storage. Same table also depicts data for total sugars which shows that total sugar of product during the storage period increased between the regular storage intervals non significantly. The increase in total sugar during the storage might be due to the hydrolysis of polysaccharide into monosaccharide and disaccharide or polysaccharides like pectic acid into starch.

Table 4.50 Effect of Storage intervals on sugar composition of rusk

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Total Sugar **(%)**	14.02±1.29	14.05±1.38	14.05±1.38	14.07±1.38	14.08±1.17
Reducing Sugar **(%)**	6.15±0.72	6.16±0.72	6.20±0.72	6.20±0.72	6.26±0.84
Non- Reducing **(%)**	7.90±0.50	7.89±0.59	7.84±0.61	7.84±0.61	7.81±0.51

ii. Effect of storage on reducing, non reducing and total sugar composition of soup sticks

In soup sticks the reducing sugars increased non significantly with the values as 2.44, 2.45, 2.47, 2.47, 2.49 for 0, 30, 60, 90, and 120 days respectively. This could be due to the hydrolysis of sucrose. During the storage period the non reducing sugars in soup sticks decreased non significantly between the storage intervals with values as 7.64, 7.60,7.60, 7.59, 7.57 for 0, 30, 60, 90 and 120 days of storage respectively. Which might be due to the hydrolysis of non reducing sugars to reducing sugars. Table 4.51 reveals the data for total sugars which shows that total sugar of product during the storage period increased between the regular storage intervals. This could be attributed to the hydrolysis of the polysaccharides.

Table 4.51 Effect of storage intervals on sugar composition of soup sticks

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Total Sugar **(%)**	10.05±4.00	10.09±3.92	10.09±3.92	10.1±3.93	10.05±4.00
Reducing Sugar **(%)**	2.44±2.44	2.45±0.40	2.47±0.40	2.47±0.40	2.49±0.41
Non- Reducing **(%)**	7.64±1.67	7.60±1.66	7.60±1.66	7.59±1.66	7.57±1.66

iii. Effect of storage on reducing, non reducing and total sugar composition of kurkure

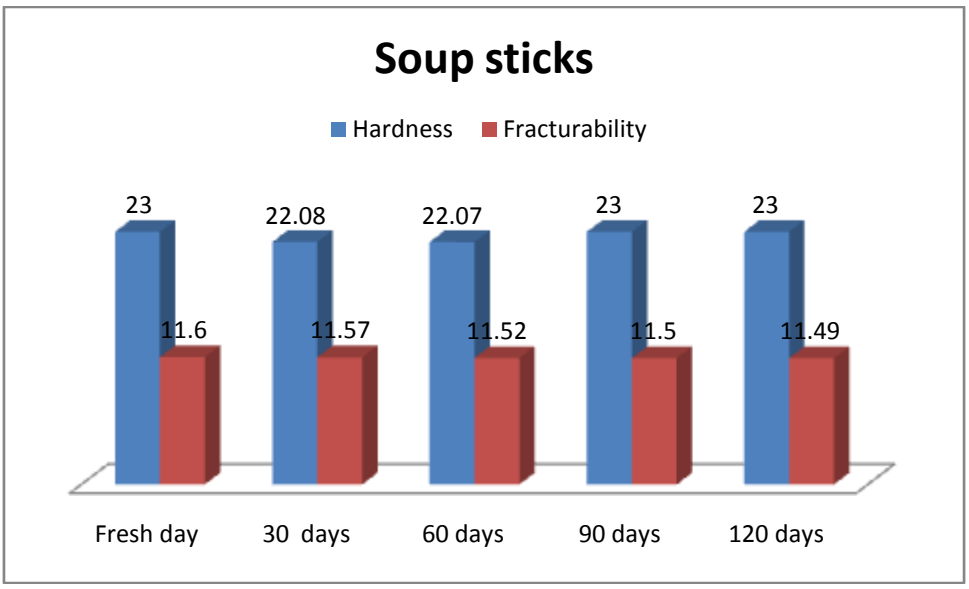
Reducing sugars increased non significantly in soup sticks within the storage period with values recorded as 0.09, 0.11, 0.11, 0.14, 0.16 for 0, 30, 60, 90, and 120 days respectively. This might be due to the hydrolysis of sucrose to glucose and fructose. The non reducing sugars of kurkure decrease non significantly between the storage intervals with the values as 0.18, 0.18, 0.16, 0.15 and 0.12 for 0, 30, 60, 90 and 120 days of storage respectively, which might be due to the hydrolysis of non reducing sugars to reducing sugars. Table 4.52 reveals the data for total sugars which shows that total sugar of product during the storage period increased overall and between the regular storage intervals non significantly. This might be due to the hydrolysis of polysaccharide into monosaccharide and disaccharide or polysaccharides like pectic acid into starch.

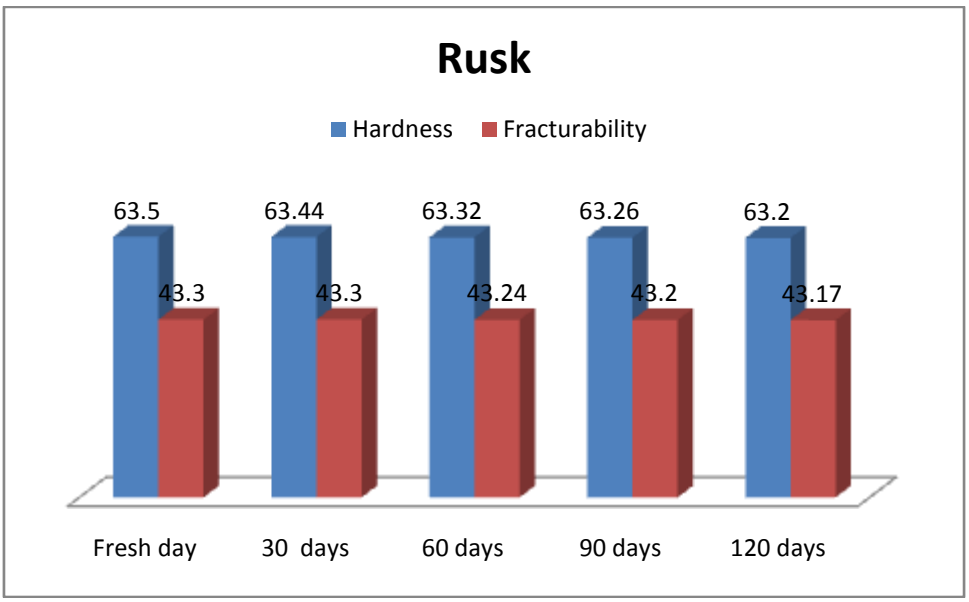
Table 4.52 Effect of storage intervals on sugar composition of kurkure

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Total Sugar **(%)**	0.26±0.02	0.29±0.02	0.29±0.02	0.30±0.02	0.32±0.02
Reducing Sugar **(%)**	0.09±0.07	0.11±0.08	0.11±0.08	0.14±0.08	0.16±0.09
Non- Reducing **(%)**	0.18±0.02	0.18±0.02	0.16±0.03	0.15±0.03	0.12±0.04

4.4.5 Effect of storage on the texture of prepared products:

During storage study change in texture take place Plate 4.8 represent the graph for pertinent data. In soup sticks there was decrease in hardness and fructurability non significantly. In case of rusk and kurkue the trend remains same and it was observed that the hard ness and the fructurability decreased non significantly within the storage period. This decrease in the texture profile during the storage study might be due to the increase in moisture content. In 2017, Singh et al. studied the texture profile of maize and chick pea based snacks and found slight decrease in the hardness of the product during storage study of 90 days.





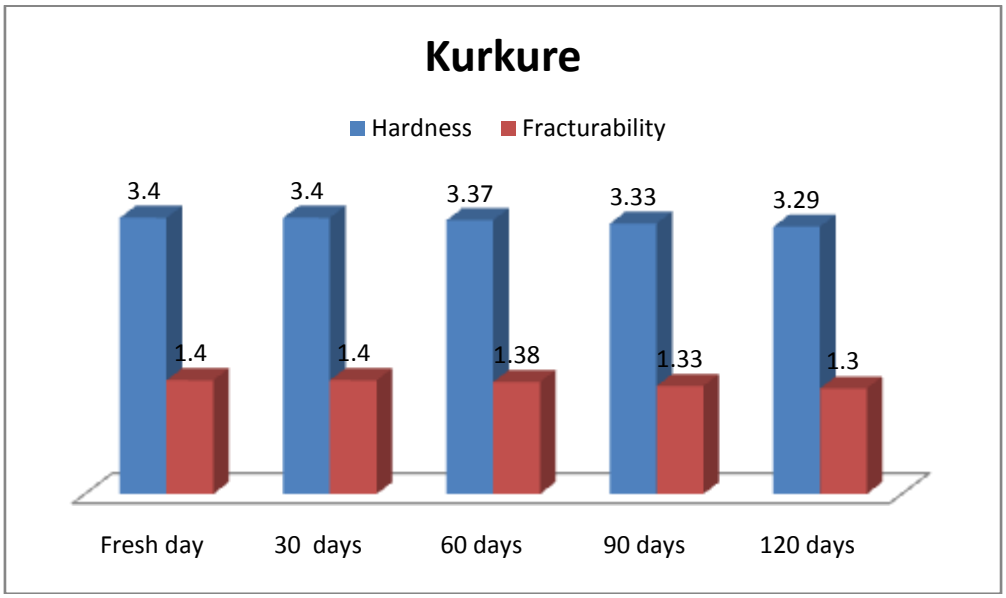


Plate 4.8: Effect of Storage intervals on prepared products Fructability (N) and Texture

4.3.5 Organoleptic Evaluation of freshly prepared product:

The prepared products were offered to a panel of judges to evaluate their sensory characteristics. The consumers' preferences for respective sensory parameters are depicted in Table 4.53.

i. Colour

Score for colour of freshly prepared products were recorded as 7.70 for bread, 6.50 for soup sticks, 6.20 for rusk and 7.00 for kurkure at fresh day storage.

ii. Flavour

Flavour of freshly prepared products scored as 7.00, 7.00, 5.70, 7.00 for bread, soup sticks, rusk and kurkure for fresh day of analysis.

iii. Taste

On the day of processing the data for taste as recorded in table 4.38 was evaluated as follows bread 6.50, for soup sticks 6.50, for rusk 5.60 and for kurkure 6.90 respectively for fresh day.

iv. Texture

Same table reveals the data for texture of freshly prepared products that were recorded as 7.50, 7.00, 7.50, and 8.10 for bread, soup sticks, rusk and kurkure respectively.

v. Overall acceptability

Table 4.53 reveals the data for overall acceptability for freshly prepared products and the data recorded was as 7.20, 6.75, 6.25, and 7.25 for bread, soup sticks, rusk and kurkure respectively.

Table 4.53 Organolaptic evaluation of freshly prepared products

	Colour	Flavor	Taste	Texture	Overall acceptability
Bread	7.70±0.67	7.00±0.81	6.50±1.08	7.50±1.17	7.20±0.58
Soup sticks	6.50±1.08	7.00±0.94	6.50±1.08	7.00±1.05	6.75±0.54
Rusk	6.20. ±1.03	5.70±1.25	5.60±1.07	7.50±1.17	6.25±0.48
Kurkure	7.00±1.05	7.00±0.81	6.90±0.87	8.10±0.87	7.25±0.40

4.4.6 Effect of storage on the sensory evaluation of the products:

i. Soup sticks

The colour of soup sticks also decrease significantly during the storage period but the difference in colour between the regular time intervals was non significant. Difference between (0-120 and 0-90 days) were significant with the value 6.50- 5.50 and 6.50- 5.90 respectively which might be due to the reaction between the amino acid and the sugars. In soup sticks the decrease in flavor was significant but the decrease in flavour between the regular time interval of storage was non significant. The differences between the 0-120 reported the values 7.00- 5.80. This might be due to the biochemical changes during storage which affect the taste of the product. In soup stick the decrease in taste was significant but the difference between the regular interval of storage period were non significant with the values of 6.50, 6.10, 5.90, 5.90, 5.40 for a time period of 0, 30, 60, 90 and 120 days of storage respectively which might be due to the degradation of some acids present in the food product (ascorbic acid) coupled with other biochemical changes in the food product during storage period. In soup stick there was decrease in texture significantly but the decrease between the 60 and 90 days was non significant. In soup sticks the decrease in overall acceptability was significant. The decrease between the regular intervals of storage was non significant but the difference between 0-120, 0- 60, 0-90 and 30-120, 30-90, and between 60-120 days were significant with the values 6.75- 5.60, 6.75-

6.12, 6.75 – 6.12 and 6.37- 5.60, 6.37- 6.12 and 16.12 – 5.60 respectively which might be due to the decrease in flavour of the product during storage.

4.54 Effect of storage intervals on sensory character sticks of soup sticks

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Colour	6.50±1.08	6.20±0.78	5.90±0.56	5.90±0.56	5.50±0.70
Flavour	7.00±0.94	6.60±0.69	6.40±0.69	6.40±0.69	5.80±0.94
Taste	6.50±1.08	6.10±0.73	5.90±0.82	5.9±0.51	5.40±0.51
Texture	7.00±1.05	6.60±1.07	6.30±0.82	6.30±1.10	5.70±0.82
Overall acceptability	6.75±0.54	6.37±0.42	6.12±0.41	6.12±0.41	5.60±0.35

ii. Rusk

Same trend was observed as in rusk colour, where the decrease was significant but, between the regular intervals of storage period the decrease was non significant and the difference between the 0-120 and 0-90 were significant with the values 6.20- 5.30, 6.20- 5.30 respectively. This might be due to the interaction of acids and the sugars. In rusk the decrease in flavor was significant but the decrease between the regular interval of storage were non significant and the difference between the, 0-120 was significant with the values 5.70 – 4.90 respectively which might be due to the biochemical changes occur during the storage period of time. In case of rusk there was significantly decrease in texture was observed. This might be due to the increase in the moisture content during storage. In overall acceptability the decrease was significant and the decrease between the regular intervals was non significant observed which might be due to the biochemical change which affect the taste of the product during storage. Nazni and Karuna (2016) analysed the rush for sensory qualities during storage study of one month and reported the results inline with the present study.

4.55 Effect of Storage intervals on sensory charactersticks of rusk

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Colour	6.20±1.03	5.90±0.73	5.70±0.67	5.30±0.67	5.30±0.94
Flavour	5.70±1.25	5.40±0.69	5.10±0.87	5.00±0.94	4.90±0.73
Taste	5.60±1.07	5.20±0.78	5.00±0.81	4.90±0.87	4.70±0.67
Texture	7.50±1.17	7.00±0.81	6.60±0.69	6.20±1.13	5.90±1.19
Overall acceptability	6.25±0.48	5.87±0.33	5.60±0.41	5.35±0.33	5.20±0.34

iii. Kurkure

The decrease in colour of kurkure between the regular interval of storage were found to be non significant. The significant decrease in the colour might be due to the reaction between the amino acid and the sugars. In kurkure the decrease in taste was also non significant between the regular time intervals of storage. This might be due to the degradation of some acids present in the food product coupled biochemical changes in the food product during storage period. In case of kurkure there was non significant decrease in texture between the regular storage intervals. Exactly same trend of overall acceptability of rusk was followed as the decrease in overall acceptability was significant and the decrease between the regular intervals was non significant. Balfour et al. (2014) also reported the decline in sensory quality of extruded fortified snack self stability during storage study of 60 days.

4.56 Effect of storage intervals on sensory character sticks of kurkure

Storage / Parameters	Fresh day	30 days	60 days	90 days	120 days
Colour	7.00±1.05	7.00±1.05	6.80±0.91	6.70±0.82	6.60±0.69
Flavour	7.00±0.81	6.90±0.87	6.80±0.78	6.60±0.69	6.40±0.52
Taste	6.90±0.87	6.90±0.87	6.70±0.82	6.60±0.69	6.30±0.48
Texture	8.10±0.87	8.10±0.87	8.00±0.81	7.80±0.63	7.60±0.67
Overall acceptability	7.25±0.40	7.22±0.36	7.07±0.42	6.92±0.33	6.72±0.39

5. SUMMARY AND CONCLUSIONS

Cereals and pulses occupied an indespensible position in human life particularly in the dietary pattern. Cereals and pulses which are considered as poor man's meat are also excellent sources of dietary components particularly carbohydrates (starch and dietary fiber), protein, minerals and vitamins. They also hold considerable range of phenolic compounds. Though the cereals and legumes are unique in their individual nutrient composition, health benefits and other functional properties. Cereals are limiting in one of the essential amino acid lysine which is abundant in pulses. On the other hand, methionine is complemented by cereal protein which is less in legume. Hence, the overall protein quality, nutritional value and health promotion further more increases when cereals and legumes are combined together. Pulses, because of their role in improving sustainability, notably through soil management, also impact food security. By improving the crop patterns using pulses, farmers can improve their yields and limit the long-term threat to food security.

Functional foods offer great potential to improve human health and/or help to prevent certain diseases when taken as part of a balanced diet coupled with healthy lifestyle. Functional foods provide new opportunities with great expectation for both the food industry and nutrition research. The concept of functional food includes food or food ingredients that exert a beneficial effect on host health or reduce the risk of chronic diseases beyond the basic nutrition.

So the present investigation entitled " Characterization of selected cereals and pulses for the development of functional foods " was undertaken with the following objectives; Screening and identification of high fiber and low protein coarser grains / pulses; Optimization of baked and extruded snacks using identified sources; Physico-chemical, functional and quality assessment of developed food matrix and Assessment of sensory and self-stability of developed products.

The study was planned and conducted in the Department of Food Science, Nutrition and Technology, College of Home Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, District Kangra during the period 2014 – 2018 to explore

the selected seven cereals and pulses crops of the importance of state. Quality evaluation of these selected crops has been done. These were analysed for their nutritional profile, functional properties as well as antioxidant activities . Along with this an attempt was also made to develop various value added products which were analyzed for their quality parameters and storage stability was also assessed.

The results of present study reveal that colour of the cereal crops observed as cream, gray, red, reddish brown for oat, pearl millet, sorghum and finger millet respectively. Shapes of the cereals crops were found to be elongated spindle and round for oat and finger millet while oval for pearl millet and sorghum. The average thousand kernel weight obtained highest in sorghum (31.73g) and minimum in finger millet (2.31g). The porosity was found to be highest in finger millet (46.94g/100g) and minimum in pearl millet (20.12g/100g).

As far as the data of functional properties of cereal crops concerned it was found that water absorption capacity and oil absorption capacity observed highest in oat i.e. 189.00 & 205.00 per cent while minimum in sorghum 61.03 & 76.23 per cent respectively. Forming capacity and forming stability observed high in finger millet as 63.00 & 51.00 per cent and low in oat as 18.00 & 12.00 per cent respectively.

Cereal crops namely oat, pearl millet, sorghum and finger millet contained 3.50, 2.48, 1.43, 2.41 per cent ash. The highest crude fiber and highest crude fat was found to be in oat as 5.34 & 4.95 per cent respectively. The lowest amount of crude fiber and crude fat was observed in sorghum and finger millet i.e. 2.35 & 2.00 per cent respectively. Out of selected cereals crops finger millet contained least amount of protein i.e. 7.45 per cent.

In nutritional composition of selected cereal crops (oat, pearl millet, sorghum and finger millet), finger millet obtained maximum values for ADF (5.86), NDF (11.29), lignin (1.10), hemicelluloses (5.76) and cellulose (5.56) while ADF (2.02) found on lower side in oat and NDF (5.56) , lignin (0.23) and hemicelluloses (2.44) observed less in pearl millet. The cellulose content was observed low in oat i.e. 1.39 per cent. Sorghum contained highest total dietary fiber i.e. 17.92 per cent whereas, pearl millet contained lowest as 8.91 per cent. Sugar content was observed high in pearl millet and low in finger millet as 2.88 and 1.69 per cent respectively.

Selected cereals crops were loaded with minerals. Finger millet was observed rich in calcium and magnesium as 269.54 & 343.00 mg/100g respectively while oat was found to be rich in phosphorous and potassium as 381.02 & 379.46mg/100g respectively. The highest amount of iron and zinc was observed to be in pearl millet (12.08 and 3.03 mg/100g).

Amino acid profile in selected cereals was found to be excellent. In sorghum , amino acid distribution was found good out of selected cereals as histidine, isolucin, methionin phynile alanine, threonine, tryptophan and valine attained maximum values as 1965, 6791, 2320, 3769, 6810, 1863 and 6459 µg/100g respectively.

As far as the data of starch, resistance starch and glycemic index is concerned. Oat and rice bean attained the maximum value for the resistant starch as 2.69; 2.58 per cent and the maximum value for amylose content was found in oat and chick pea i.e. 18.20 and 13.32 per cent respectively. All the selected cereals and pulses came under the class of low glycemic index food.

As far as phytochemicals content like saponins and tannins are concerned, maximum values were attained in finger millet and pearl millet as 5.29 and 228.00 mg/100g respectively.

The data of selected pulse crops *viz.* horse gram, chick pea and rice bean reveals the colour as black, pale cream, pale green respectively. The shapes of selected pulse observed as flat ellipsoidal, irregular and cylindrical for horse gram, chick pea and rice bean respectively. Thousand kernel weight was observed highest in chick pea 391.00 g among the selected pulses and minimum in horse gram i.e. 32.69 g. Whereas, rest of the pulses obtained the intermeditartry values.

Functional properties of the selected pulses was observed to be good. Chick pea attained maximum values for all the functional parameters i.e. water absorption capacity, oil absorption capacity, foaming capacity, foaming stability and water solubility index as 73.38, 86.05, 54.00,45.00 percent and 23.64g/g respectively except water absorption index which was found highest in horse gram i.e. 7.24 per cent.

Selected pulse crops i.e. horse gram, chick pea and rice bean contained 6.65, 7.43 and 9.53 per cent moisture content respectively. The highest crude fiber lowest

fat and protein values were observed to be in horse gram as 5.40, 1.80 and 21.28 per cent respectively. As far as the data is concerned for nutritional composition of selected pulse crops, the values for ADF, lignin and cellulose were found to be on the higher side in horse gram as 6.37, 0.46 and 5.91 per cent respectively, whereas the value for NDF, hemicellulose and dietary fiber was observed miximum chick pea with values 16.02, 10.04 and 22.38 per cent respectively. The total sugars content was found to be high in chick pea and low in horse gram with the values 6.56 and 1.91 per cent respectively.

Minerals composition of selected pulse crops were also evaluated and the results reveal that maximum values for Ca and Mg i.e. 485.11 and 345.36mg/100g assessed in rice bean. Whereas, chickpea obtained maximum values for P, K, Fe and Zn as 695.10, 670.14, 7.15 & 3.58 respectively.

Selected pulse crops namely horse gram, chick pea, rice bean had attained good amino acid contents. Histidine and methionine was found high in rice bean as 3438 and 6837.00 µg/100g respectively. Isolucine, leucine, lysine and tryptophan were observed to be high in horse gram with the values 6789, 11941, 94912 and 2019 µg/100g respectively whereas, phynilealanine, threonine, valine and aspartic was found high in chick pea with the value 3405, 6810, 6519 and 10908µg/100g respectively.

The saponins and tannins content among the selected pulse crops, chick pea contained the maximum value for saponin (4.78) followed by rice bean (0.20) & horse gram (0.11). Whereas, maximum value for tannin is obtained in rice bean (228.00), minimum in chick pea (0.90) while horse gram attained the intermediately value (107.00) mg/100g.

Antioxidant activity of all the seven cereal and pulse crops was found good. The total phenolic content ranged as 1.14 - 0.14 mgGAE/g, flavonoid in the range of 1.20- 0.013 mgQE/g and FRAP in the range of 1.20-0.09 mg/g. Whereas, DPPH content was found to be at 62.16 – 51.10 per cet at 50 per cent inhibition.

Cereals and pulses complements each other in many ways, so efforts were made to develop the value added products with the selected crops like bread, soup sticks, rusk and kurkure by appling Response Surface Methodology with design

expert 9 software. For bread best composition came out to be in the proportion of 10 : 35 : 27 : 13 : 15 for wheat, oat, finger millet pearl millet and sorghum respectively; for soup sticks the best blending propotion for wheat, chick pea, rice bean, and horse gram obtained as 10 : 42 : 27 : 13 g respectively. Similarly for rusk, the proportion worked out to be as 10 : 36 : 33 : 7 : 4 g respectively for wheat , oat, finger millet, pearl millet and sorghum. Whereas, kurkure was prepared by using the blend of of wheat, oat, finger millet, pearl millet, sorghum, chick pea, rice bean and horse gram in the level of 9 : 21 : 17 : 4 : 16 : 18 : 3 : 15g respectively.

Fresh analysis of products depicted that they had good ash content but the highest observed to be in kurkure with the value of 6.12 percent. The highest crude fiber was observed to be in bread and kurkure i.e. 0.29 per cent, while crude fat and crude protein content was found minimum in kurkure i.e. 0.23 and 3.27 per cent respectively.

Developed products contained the good amount of minerals. The calcium, magnesium and potassium content to be found highest in bread amongst the developed products as the values were calculated as 49.36, 21.56, 46.00 mg/100g respectively. Whereas, iron and zinc content was observed high in rusk as 4.71 and 2.21 mg/100g respectively.

In freshly prepared products the starch, resistant starch , amylose and glycemic index was observed highest in bread with the values as 36.54, 4.52, 10.45 and 52.00g/100g respectively. The minimum value for starch attained in soup sticks (18.71 g/100g) and amylose & resistant starch for kurkure as 2.54 per cent respectively. Glycemic index was found minimum in soup sticks sample.

Sensory evaluation of freshly prepared products reveals that bread observed to best as a colour perception. But on the basis of taste and texture, consumers preferred kurkure. Rusk scored as 5.60 and 5.70 for taste and flavour. On the basis of textural scores, soup sticks were less preferred whereas, kurkure prefrred with maximum overall acceptability.

Conclusion:

From the aforesaid discussion, it is concluded that Response Surface methodology (RSM) serves as an effective tool to get optimized blend of different cereals : pulses for the preparation of the baked and extruded products.

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APPENDICES

Appendix I

0.1N Ferricyanide Maltose Sucrose Conversion Table*

0.1N Ferricyanide Reduced , ml	Maltose per 10 g flour, mg	Sucrose per 10g Flour, mg	0.1N Ferricyanide Reduced, ml	Maltose per 10g Flour, mg	Sucrose per 10g Flour, mg
0.10	5	5	4.50	237	214
0.20	10	10	4.50	244	218
0.30	15	15	4.70	251	223
0.40	20	19	4.80	257	228
0.50	25	24	4.90	264	233
0.60	31	29	5.00	270	230
0.70	36	34	5.10	278	242
0.80	41	38	5.20	282	247
0.90	46	43	5.30	288	251
1.00	51	48	5.40	295	256
1.10	56	52	5.50	302	261
1.20	60	57	5.60	308	266
1.30	65	62	5.70	315	270
1.40	71	67	5.80	322	275
1.50	76	71	5.90	328	280
1.60	80	76	6.00	334	285
1.70	85	81	6.10	341	290
1.80	90	86	6.20	347	294
1.90	96	91	6.30	353	299
2.00	101	95	6.40	360	304
2.10	106	100	6.50	367	309

0.1N Ferricyanide Reduced , ml	Maltose per 10 g flour, mg	Sucrose per 10g Flour, mg	0.1N Ferricyanide Reduced, ml	Maltose per 10g Flour, mg	Sucrose per 10g Flour, mg
2.20	111	104	6.60	373	313
2.30	116	109	6.70	379	318
2.40	121	114	6.80	385	323
2.50	126	119	6.90	392	328
2.60	130	123	7.00	398	333
2.70	135	128	7.10	406	337
2.80	140	133	7.20	412	342
2.90	145	138	7.30	418	347
3.00	151	143	7.40	425	352
3.10	156	148	7.50	431	357
3.20	161	152	7.60	438	362
3.30	166	157	7.70	445	367
3.40	171	161	7.80	451	372
3.50	176	166	7.90	458	377
3.60	182	171	8.00	465	382
3.70	188	176	8.10	472	387
3.80	195	181	8.20	478	392
3.90	201	185	8.30	485	397
4.00	207	190	8.40	492	402
4.10	213	195	8.50	499	407
4.20	218	200	8.60	505	-
4.30	225	204	8.70	512	-
4.40	231	209	8.80	519	-

*** AOAC (2010)**

APPENDIX-II

Organoleptic Evaluation form

Sample : _____ Date : _____

Sample	Perfect	Good				Fair		Poor		Off	Remarks
	10	9	8	7	6	5	4	3	2	1	0

Note: Make check mark in columns corresponding to your rating of sample, when scorning one factor. However, when scorning 2 or more factors, write in the following letter in the corresponding column of columns (C) colour (E) Flavour (T) Texture (S) Taste

APPENDIX-III

Recipe of Bread

Ingredients:
Flour 100.00g, yeast2.00g, oil 5.00g, sugar 5.00g and water for dough making

Method:

First of all activation of yeast was done by adding it in luke warm water with sugar and kept aside to rise. Then added the one teaspoon of oil to the flour in a bowl and mixed well. Kneaded it to make soft and smooth dough. Covered the dough with muslin cloth and left it to rise for about one hour. After this knocked back the dough again get to soft and smooth dough. Then half filled the greased loaf pan with dough and allowed it for final rise for about 30 minutes. Then baked in preheated oven at 80^{o}C for 45 minutes. Cooled to room temperature and sliced.

Recipe of Soup sticks

Ingredients:
Flour 100.00g, yeast 2.00g, oil 5.00g, sugar 5.00g and water for dough making

Method:

First of all activation of yeast was done by adding it in luke warm water with sugar and kept aside to rise. Then added the one teaspoon of oil to the flour in a bowl and mixed well. Kneaded it to make soft and smooth dough. Covered the dough with muslin cloth and left it to rise for about one hour. After this knocked back it again to soft and smooth dough. Rolled the dough into small pieces and shaped them like pencil. Transferred to a greased oven tray and baked in preheated oven at 80^{0}C for 35 minutes. Cooled to room temperature and packed.

Recipe of Rusk

Ingredients:
Flour 100.00g, yeast 2.00g, oil 5.00 ml, sugar 15.00g and water for dough making

Method:

First of all activation of yeast was done by adding it in luke warm water with sugar and kept aside to rise. Then added the one teaspoon of oil to the flour and sugar in a bowl and mixed well. Kneaded it to make soft and smooth dough. Covered the dough with muslin cloth and left it to rise for about one hour. After this knocked back the dough again to soft and smooth dough. Then half filled the greased loaf pan with dough and allowed it for final rise for about 30 minutes. Then baked in preheated oven at 80^0C for 45 minutes. Cooled to room temperature and sliced. Baked again for making crunchy rusks.

Brief Biodata of student

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High school (Matriculation)	2005	H.P Board	70.43	1st	Math , Science, English, Social – Science, Hindi, Sanskrit, I.T
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B.Sc.	2011	CSK HP KV PALAMPUR	72.70	1ST	Home Science with Elective Dietetics and Catering Management
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Research Papers: 4
Poster pre+sentation: 4