STUDIES ON DEVELOPMENT OF PEARL MILLET CRACKERS INCORPORATED WITH SORGHUM AND SOYBEAN FLOUR

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B.Tech. (Food Technology)

MASTER OF TECHNOLOGY

IN

FOOD TECHNOLOGY

DEPARTMENT OF FOOD CHEMISTRY AND NUTRITION

COLLEGE OF FOOD TECHNOLOGY, PARBHANI

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PARBHANI - 431 402 (M.S.) INDIA

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By

PANDIT MINAL GAUTAM

B. Tech. (Food Technology)

A thesis submitted to

Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani

in partial fulfillment of the requirements for the degree of

MASTER OF TECHNOLOGY

IN

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2021

CONTENTS

DECLARATION BY THE CANDIDATE

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CERTIFICATE –II

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W	URL: http://repository.sustech.edu/bitstream/handle/123456789/19965/Production%20of%20Biscuits.....pdf?isAllowed=y&sequence=3 Fetched: 4/17/2021 7:03:42 AM	1
W	URL: http://www.foodsciencejournal.com/download/340/3-1-38-378.pdf Fetched: 4/6/2021 7:26:20 PM	1
W	URL: https://www.ijcmas.com/6-7-2017/S.D.%20Patekar,%20et%20al.pdf Fetched: 5/19/2021 5:24:50 AM	4
W	URL: https://docplayer.net/103944382-Studies-on-development-of-functional-wheat-bread-supplemented-with-stabilized-rice-bran.html Fetched: 6/14/2020 12:14:47 AM	13
W	URL: https://core.ac.uk/download/pdf/84886566.pdf Fetched: 7/28/2021 7:33:00 AM	1
J	**DEVELOPMENT OF SNACK CRACKERS INCORPORATED WITH DEFATTED COCONUT FLOUR** URL: cdf99da2-4e1d-4f91-bf4c-1e92e2bea0f0 Fetched: 3/28/2019 8:53:48 PM	5
W	URL: https://www.researchgate.net/publication/331550880_Development_and_Analysis_of_Sorghum_Crackers Fetched: 7/28/2021 7:33:00 AM	1
W	URL: http://www.chemijournal.com/archives/2020/vol8issue4/PartAH/8-4-339-855.pdf Fetched: 12/26/2020 6:21:59 AM	3
W	URL: https://www.researchgate.net/publication/329237150_Studies_on_development_of_high_protein_cookies Fetched: 7/10/2021 7:16:23 PM	4
W	URL: http://dspace.lpu.in:8080/jspui/bitstream/123456789/3039/1/11708386_5_12_2018%203_53_44%20PM_FINNAL%20pdf%201.pdf Fetched: 4/28/2021 12:43:40 AM	1
W	URL: https://www.phytojournal.com/archives/2017/vol6issue5/PartK/6-4-453-508.pdf Fetched: 12/15/2020 8:17:21 AM	3

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LIST OF TABLES

LIST OF FIGURES

LIST OF FLOW CHART

LIST OF PLATES

ABBREVIATIONS USED

Abbreviation		Elaboration
RH	:	Relative Humidity
%	:	per cent
CD	:	Critical Difference
cm	:	Centimeter
SE	:	Standard Error
WVTR	:	Water Vapor Transmission Rate
mg	:	Milli gram
G	:	Gram
kg	:	Kilogram
ºC	:	Degree Celsius
psi	:	Pressure per square inch
et al.	:	et alibi (and associates)
hr	:	Hour
i.e.	:	That is
kcal	:	Kilo Calorie
No.	:	Number
etc	:	Etcetera
TPA	:	Texture Profile Analysis
cfu	:	Colony Forming Unit
HDPE	:	High Density Poly Ethylene
PP	:	Poly Propylene
min	:	Minute
ml	:	Mililiter
Rs	:	Rupees
sec	:	Second
N	:	Normality

THESIS ABSTRACT

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Title of the thesis	:	STUDIES ON DEVELOPMENT OF PEARL MILLET CRACKERS INCORPORATED WITH SORGHUM AND SOYBEAN FLOUR
Name of candidate	:	Pandit Minal Gautam
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ABSTRACT

In the present investigation, the technology was developed to standardize the process for preparation of pearl millet crackers incorporated with sorghum and soybean flour. Crackers are bakery product commercially prepared using refined whole wheat flour. From previous years, crackers have been prepared from refined wheat flour which is high in gluten, which causes gluten intolerance. To overcome this problem of gluten intolerance, the utilization of pearl millet in crackers will help to solve such a problem. Regarding the health benefits of pearl millet, formulated crackers will be a good source of fiber, calcium and iron. With the addition of sorghum and soybean flour, it will improve its nutritional and textural quality. The current efforts have been made to formulate the crackers by optimizing the ingredients based on quality parameters. Crackers are prepared from pearl millet, sorghum and soybean flour at the level of (60:30:10) respectively. Prepared crackers were analysed for chemical and sensory properties. Sensory evaluation revealed that the T_2 sample was better than other it contains 60% pearl millet, 30% sorghum and 10% soybean flour. The nutritional study revealed that prepared crackers sample contains fat 11%, protein14%, carbohydrate 69.06%, crude fiber 2.29% and energy value 422.24 kcal respectively. From the present investigation, it was concluded that pearl millet crackers prepared with incorporation of sorghum and soybean flour has good nutritional and sensory quality attributes.

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Keywords: Pearl Millet, Sorghum, Soybean, Crackers, Nutritional Composition.

CHAPTER – I

INTRODUCTION

CHAPTER - I

INTRODUCTION

The increasing demand of the consumer for healthy food that are best sources of good nutrition has developed the food industry to prepare food like snacks that combine convenience and nutrition. Many efforts are being made to develop snacks' nutritive value and functionality by increasing their nutritive composition. Such results are very often achieved by developing the nutrient density in basic recipes. In snack foods, crackers are a versatile food which is mostly consumed by a wide range of populations due to their diverse taste, long storage life and affordable. It gives a proper medium to fulfill consumer demand for nutritious, convenient and tasty snacks. (Ainsworth *et al.*, 2007, Ajila *et al.,* 2008; Stojceska *et al.*, 2008; Sun-waterhous *et al.,* 2010).

Epidemiological studies reveals that daily consumption of whole grain foods is used to prevent certain cancers, cardiovascular disease, type-2 diabetes and obesity (Slavin, 2004). Due to presence of the pericarp and germ components whole grains contain micronutrients such as vitamins, minerals and phytochemicals including phenolic compounds, carotenoids, vitamin E, β-glucan and sterols and dietary fibre (Fardet *et al.*, 2008). Sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) are important conventional grains of nearly 600 million nutritionally lack people in the semi-arid tropics particularly in Africa (ICRISAT). Generally developed high protein content biscuits prepared from refined sorghum flour combined with defatted soya flour can be use as a supplementary food to prevent protein energy malnutrition in children (Serrem *et al.*, 2011). Biscuits are a good medium for nutrition as a supplementary food due to their famous nature, high nutrient composition and long storage life and are ready to eat form (Sudha *et al.*, 2007).

Food and Agricultural Organization gives idea about to complete the recommended dietary allowances of infants, preschool children, adolescent girls, pregnant and lactating women need supplementary foods which are processed domestically by simple and low-cost processing technology. The need of supplementary foods is due to malnutrition problem. Supplementary foods are those which give necessary amount of nutrient when taken in less quantity. They must be prepared in form of ready-to-eat snacks, baked, drinks etc. Hence with different proportion based on cereal and legume combine food products which is important to increase the quality of Indian diet. Due to the most consumption of cereals, stability and versatility cereals are considered as most suitable medium for protein demand population. To increase the protein quality the concept of cereal-legume complementation by mixing cereal and legume flours can be applied (FAO/WHO, 1994).

Gluten-free products that exchange important basic foods e.g. flour, bread, pasta should give near amount of all the same quantity of vitamins and minerals as the original food replaced (FAO/WHO, 1994). The energy and nutrient composition of gluten-free products require awareness as the replacement of wheat flour with gluten-free alternatives may result in poor intake of important nutrients (Hager *et al.*, 2012). Bakery is the quick growing part of gluten-free products, because of increasing availability of gluten-free flour alternatives. Using gluten free flour for preparation of biscuit is easier than other bakery products since the structure of biscuits does not depend as much on the protein network as it does on the starch gelatinization (Dicairano *et al.*, 2018). As well, profit oriented possibility of several types of gluten-free flours is look forward to increase the market income growth in future.

Celiac disease also called as gluten intolerance, act on those people who are genetically intolerant to gluten (Sheasby, 2001). Gluten is a protein that occurs naturally in wheat and rye and is like to similar proteins in oats and barley. Hence gluten is present in all foods that are made from these grains. When celiac patient eat food which contain gluten then intestine acts to the food as an allergy. The lining of the intestine becomes swollen and this causes the villi to become flattened, reducing the surface area of the gut which is then no longer able to absorb nutrients properly (Corcoran, 2006). Weight decreases and dissipating may then occur, chief malnutrition occurs (Sheasby, 2001). Acute symptoms such as chronic abdominal bloating and pain, diarrhea, constipation, weight loss and sometimes blistery rash have been occurred (Corcoran, 2006). Gluten intolerance causes Dermatitis Herpetiform is that affects the skin by forming lesions that are watery and itchy (Gluten Intolerance & Celiac Disease, 2006). The better treatment is consuming gluten free diet (Corcoran, 2006; Sheasby, 2001; Feighry, 1999). Respective on any escape diet are at risk of developing deficiencies of micro-nutrients e.g., thiamine, riboflavin, niacin, iron, selenium, chromium, magnesium, phosphorus and molybdenum (Steinman, 2007).

In India Bakery industry is known as one of the major food processing industries with an annual demand of over 2758 MT. Crackers are thin, crisp biscuits or wafers prepared from unraised and unsweetened dough. Crackers are hard baked products prepared from flour and contain small amount of moisture. These are adaptable convenience foods. Crackers are work as snacks, light meal supplement, appetizers. Earlier consumers are more focused in food products that are made from healthier ingredients. Crackers are often identifying as nutritious and convenient way to consume a staple food or cereal grain (Shere *et al.,* 2018). Generally crackers are extensive products similar to semi sweet machine cut cookies to fermented, crisp, non-sweet and laminated items. The crackers are like to the chemically leavened products containing the categories of the semi-sweet gram crackers and the mostly flavoured snack crackers with pre dominant onion, garlic, caraway, smoked yeast and cheese etc. flavours (EIRI Consultants and Engineers).

A processed food products are a bakery product prepared from wheat flour and different other ingredients, made for utilization through the process of baking. Generally bakery product contain breads, cakes, pies sweet rolls buns cookies cracker, ice cream cones etc **(**Ellis, 1990). In the biscuits and cracker industry, the idea about biscuits and cookie are used interchangeably. A cookie in the United States is a biscuits in England, Canada and many other countries. It is recognise that the term biscuits not called baking powder biscuits and muffins etc **(**Ellis, 1990**).** Due to all used long shelf-life bread substitutes biscuits can be called as crackers (Duncun, 2001). The cracker known as thin bread simillar products which may be prepared through fermented dough methods examples are soda cracker's saltines or in a non fermented dough process as ingraham crackers and some snack cracker **(**Ellis, 1990). Generally crackers contain small amount or no sugar but medium levels of fat and normally contains low amount of water. The consumer way of behaving is 13.79 % impact by healthy factor (Jaisam & Utama-ang, 2008). The consumer desire healthy food prepared from natural ingredients rather than the artificial and chemical ingredients because of good health.

Especially bakery products are emerging functional snack foods in the food industry with potential health benefits are most in demand by consumers. Many studies have evaluate the production of bakery products such as bread, biscuits, cookies and crackers with health providing ingredients such as pulses, grains and tubers (Julianti *et al.*, 2017; Ahmed & Abozed, 2015; Dokic *et al.*, 2015; Shedej *et al.*, 2011). Cookies, crackers and biscuits are the baked snack products. Crackers are adaptable thin and crispy food that can interest a variety of consumer demands. They work as a quick snack with less content of moisture, sugar and fat. Crackers can be classified into mostly three categories such as soda crackers, snack crackers and savory crackers (Ahmed & Abozed, 2015). The main ingredient in crackers is wheat flour whose utilization may cause celiac disease is a serious fraction (1:100-1:200) of the global population. Gluten is the major contain in wheat flour that effects this inflammatory disease response. Hence need for food producer to provide replacement of gluten-free bakery products. While gluten free alternatives for bakery products such as bread, cakes and biscuits are widely available alternatives to crackers are not common especially in Thailand.

Pearl millet (*Pennisetum glaucum*) is a flexible cereal develop for food, feed and for ages (Arora *et al*., 2003) mostly in African and Asian countries (Nambiar *et al*., 2011). Around all the millet varieties, 29 million hectare occupied by pearl millet however its distribution is restricted geographically mainly in Africa (15 million) and Asia (11 million) as being the largest producer (Rathore *et al*., 2016). The production of pearl millet is more than 95% in developing countries and India as the largest producer (Basavaraj *et al*., 2010) covers an area of 9.8 million hectares compeer to total world production (Rathore *et al*., 2016). Pearl millet contain higher protein 14.0 %, fat 5.7 %, fiber 2.0% and ash 2.1 % content (Sade, 2009) with compared to the major cultivated cereal crops such as wheat (Kavitha & Parimalavalli, 2014) and sorghum (Awadelkareem *et al*., 2015). Pearl millet contain good protein quality in term of its tryptophan and threonine content (Elyas *et al*., 2002) along with higher content of calcium, iron as well as zinc (Yadav *et al*., 2014; Sade, 2009; Lestienne *et al*., 2007) makes this crop very useful for human. Energy content of pearl millet is greater than sorghum and equivalent to brown rice due to its rich unsaturated fatty acids 75 % and linoleic acid 46.3 % contents (Jaybhaye *et al*., 2014).

In western india (Gujarat, Rajasthan and Haryana) Pearl millet is an imortant coarse cereal crop (Amarender *et al.,* 2013). It has possible upcoming for future human use due to its tolerance not easy growing conditions such as drought, low soil fertility and high temperature and can be grown in areas where other cereal crops such as maize (*Zea mays*) or wheat (*Triticum aestivum*) would not survive. Pearl millet is the basic staple food in poor countries and used by the low income people. It is consume in the form of variety ways including both leavened and unleavened breads, porridges and can also boiled or steamed. Pearl millet whole flour product have less demand because of it contain fibrous seed coat, coarse and grey to yellow flour which gives bitter taste to the prepared product (Olatungi *et al*., 1982). Therefore, these reason wheat and rice eaters have less demand. Pearl millet have more amount of minerals such as iron, calcium, zinc and high level of fat, it is nutritionally equivalent and even superior to major cereals because of the energy and protein value (Fasasi, 2009). Due to lack of institutional support for millet crops in comparison to the institutional promotion of wheat, rice and maize continue to decrease the millet-growing region. While pearl millet (*bajra*) is nutritious, it is less utilized in developed countries due to non-availability in convenient and ready to eat form (Obilana, 2010).

Guinea com also called sorghum (*Sorghum bicolar (L) Moench*) grain is the fifth major staple cereal after wheat, rice, maize and barley. In global warmer climates sorghum grains are cultivated, in semi-arid area like Africa, Asia and Central America sorghum is important food crop (Escoport, 2009). In Maharashtra, Karnataka and Andhra Pradesh sorghum crop is primarily develop. Madhya Pradesh, Gujarat and Rajasthan are another state for producing sorghum (Chavan *et al*., 2015). The largest producer of sorghum in the world is India with 6.98 million tons during 2010-11 and almost entire production of sorghum (95%) in the country from above regions (Dayakar *et al*., 2007 & GOI, 2011). In rural areas like central Maharashtra, per capita annual consumption of sorghum is around 60 kg, consider for almost half of per capita consumption of all cereals (Parthasarthy *et al*., 2010).

Sorghum is consumed in various forms around the world like baked bread, porridge, tortillas, couscous, gruel, steam-cooked products, alcoholic and non-alcoholic beverages etc. The potential food applications of sorghum have been reported (Brannan *et al*., 2001 and Obizoba, 1988). It is the possible to be processed into starch, flour, grits and flakes and also it is used to produce a wide range of industrial products. It can also be malted and processed into malted foods, beverages and beer. Sorghum protein is preferable to wheat protein in biological value and digestibility. Glutens are not present in sorghum and it contains more fiber and micronutrients. Though people suffering from diabetes in India are used sorghum which are digested slowly and an excellent health food (Klopfenstein and Hoseney, 1995). Several epidemiological data said that whole grain consumption remarkably lowers mortality from cardiovascular disease (Kushi *et al*., 1999; Slavin *et al*., 2000; Anderson 2003). Triglyceride lipids are mostly present in sorghum which is rich in the unsaturated fatty acids, oleic and linoleic their percentages being 33 and 47 respectively (Salunke *et al*., 1977; Hall, 2000; Kleih *et al*., 2000). Processed Food products of sorghum for human consumption are in form of flakes, pasta, vermicelli and semolina etc (Dayakar & Singh, 2010).

Soybean *(Glycine max L. Merril*) is the world's most important seed legume, which arrive to 25 % of the global edible oil about two-thirds of the world's protein concentrate for livestock feeding. Soybean meal is a helpful ingredient in formulated feeds for poultry and fish. Soybean has become an important oilseed crop in India in a very short period with approximately 10 million ha area under its cultivation. Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh and Chhattisgarh are the major soybean growing states (Agarwal *et al.,* 2013).

Legumes called as "a poor man's meat". They provide protein, complex carbohydrates, fiber and essential vitamins and minerals to the diet which are low in fat and sodium and contain no cholesterol. It contains helpful phytochemicals as well. Soybeans contain rich source of chemical substances that are not nutrients in the strict sense of the word but they are remarkably active within the body. These substances include isoflavones, phytosterols, protease inhibitors and phytic acid. The protein content of other bean is 20-25% but soybean contains about 40% protein. Soybean protein contain amino acid which are needs for body, both for adults and children. Naturally legumes proteins are deficient in sulpher containing amino acid methionine. However, soy protein contains more amount of this important amino acid to complete adult needs. Protein in just 250 g of soybean is equivalent to protein in 3 liters of milk or 1 kg of meat (Kadam *et al*., 2012).

Soybean protein contain reliable amount of essential amino acid such as histidine, isoleucine, leucine, lysine, phenylalanine, tyrosine, threonine, tryptophan and valine which is recommended for daily intake as a balanced diet (Erdman and Fordyce, 1989).

Therefore, this study investigated the effect of fortifying sorghum and soybean flour with totally replacing wheat flour by pearl millet flour on the nutritional, sensory characteristics and consumer acceptability of such pearl millet, sorghum and soybean flour crackers. The present work has been undertaken to formulate and evaluate the qualities of pearl millet crackers. The crackers were made up of gluten free flour by without fermentation hence the prepared crackers become nutritionally balanced. Considering all the above facts the present investigation was carried out with following objectives:

Objectives:

1. To study physicochemical characteristics of pearl millet, sorghum and soybean
2. To standardize recipe for preparation of crackers
3. To evaluate sensory characteristics of developed product
4. To study physicochemical, textural, microbial quality and packaging study of developed product
5. To assess the energy value and techno-economical feasibility of developed product

CHAPTER – II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

In this globalization convenience in preparation, consumption and storage of foods has become an essential need attributing to urbanization, busy lifestyle, technological advancement, increased woman employment away from homes, and numerous other factors (Perez *et. al.,* 2010).

Rapidly increasing interest in achieving wellness through diet are among the factors fuelling interest in innovative foods. This chapter deals with a compressive review of the literature relevant to the study. A review of literature is an essential and important part of scientific investigation with the purpose is to determine the previous work done and to assist in the description of objective of the hypothesis and research procedure to be followed. The related past studies on this topic are limited. The scattered literature concerning the study has been reviewed under the following headings:

2.1 Proximate analysis of raw material

2.2 Effect of pretreatment on product composition

2.3 Recipe standardization

2.4 Proximate analysis of crackers

2.5 Sensory evaluation of the crackers

2.6 Microbial study of crackers

2.7 Texture profile analysis of crackers

2.8 Packaging material study of crackers

2.1 Proximate analysis of raw material

Mustakas (1971) reported that soybean meal contains fat 20.5 percent, protein 41 percent, ash 5.3 percent, fiber 2.8 percent and carbohydrate 25.2 percent while defatted soybean meal contains protein 50.5 percent, fat 1.5 percent, ash 5.8 percent, carbohydrate 34.2 percent and fiber 3.2 percent.

Mani *et al.,* (1993) reported that pearl millet has the lowest glycemic index (55) as compared to moong bean, sorghum and finger millet.

Beta & Corke (2001) reported that the properties of sorghum starch. The starch was isolated from sorghum of 10 different genetic constitutions and its physicochemical characteristics such as amylase content, textural and thermal properties were evaluated. The amylase of the sorghum starch was about 24-30 percent. DC-75 is the highest peak viscosity was found in starch. 67–69°C is narrow range of the peak temperature of gelatinization of starch occurred. White starch is produced due to Kasvikisire and SV2 Genotypes. Different shades of pink were obtained from starches from other geno-types.

NIN (2003) stated that pearl millet consists of several essential micronutrients requred by the human body. 2.3 mg/100 g is the overall mineral content of pearl millet which is more than commonly consumed cereals. It is high in potassium, magnesium, phosphorous, zinc, copper, manganese, iron and B-vitamins.

Taylor (2004) studied that the overall fat content of pearl millet grain ranges between 1.5 to 6.8 per cent. Ash content of pearl millet between in the range of 1.6 to 3.6 g/100 g.

Anju (2005) studied conducted by on various pearl millet varieties gives a weight of 1000 seed lying in the range of 9.05 to 12.6 g, a result of this study state that seed volume and seed density range from 0.02 to 0.032 and 0.89 to 0.92 respectively.

Kishaninejad *et al.*, (2008) reported that the soaking time decreased with an increase temperature in soaking and per cent water absorption capacity of cereal grains increased when temperature of soaking rises from 25°C to 65°C.

Kibar & Ozturk (2008) mentioned that the mechanical and physical properties of soybean were determined at 8 to 16 percent moisture content. In this moisture range, grain length, width, thickness, arithmetic average diameter and geometric average diameter increased from 7.24 to 8.19, 6.79-7.12, 5.78- 6.23, 6.60-7.18, 6.57-7.14 mm respectively. The volume of grain and area of grain surface increased linearly from 130.97 to 160.32 and from 125.46 to 144.39 mm^2 respectively. The bulk density, sphericity, true density and porosity decreased linearly from 766.12-719.00, 0.91 to 0.87, 983.33-905.67 kgm^3 and 22.58 to 20.61 percent respectively. The angle of internal friction increased linearly from 27.37 to 31.81 with the increase of moisture content. The static coefficient of friction increased from 0.385 to 0.571, 0.304-0.441 and 0.164-0.286 for concrete, wood and galvanized steel surfaces respectively.

Abdalla *et al.*, (2010) reported that in pearl millet grains calcium, iron, and zinc content to be 16.08- 16.09, 17.88-18.65 and 6.7-7.29 mg/100 g respectively.

Sachin *et al.*, (2011) reported that the physical properties of soybean such as grain size, sphericity, grain volume, thousand grain weight, true density, bulk density, bulk porosity, angle of repose and static coefficient of friction were evaluated as a function of moisture content in the range of 7.37, 10.92 and 15.80 percent. The grain size increased from 5.441 to 5.571 mm grain volume increased linearly from 80 to 83.72 mm^3 whereas sphericity increased from 0.8329 to 0.8415 due to change in moisture content from 7.37 to 15.80 percent. The bulk density and true density were decreased from 749.1 to 644.4 kg/m^3 and 1250 to 1111.11 kg/m^3 respectively while the bulk porosity was increased from 40.07 to 41.9 per cent in the specified moisture content. The angle of repose and thousand grain weight increased from 26.35 to 30.96 degree and 103.57 to 109.57 g respectively as moisture content increased from 7.37 to 15.80 percent. The static coefficient of friction increased linearly against all the tested surfaces as moisture content increased.

Legesse (2013) reported that in pearl millet 11.72 per cent protein, 8.82 per cent moisture, 2.75 per cent crude fiber and 1.35 per cent ash contain.

Butti *et al.*, (2017) studied the chemical composition of various sorghum varieties such as parbhani moti, parbhani jyoti, phule vasuda, akola kranti and phule revati. Moisture content of the sorghum varieties was ranged from 12 to 13.9 per cent, protein (9.8 to 15.08 per cent), fat (3.8 to 4.71 per cent), carbohydrate (65.8 to 70.52 per cent) and the ash content of the sorghum varieties ranged 1.89 to 2.06 percent.

2.2 Effect of pretreatment on product composition

Adawy *et al.*, (2000) reported that the soybean seeds were soaked in 0.5% sodium bicarbonate in attempt to evaluate their nutritional quality and protein solubility index. Soaking process led to an increase in the hydration coefficient, seed weight, total protein, ash, fat, fiber, while non protein nitrogen, total carbohydrates, starch, stachyose, raffinose, reducing sugars and minerals except sodium were decreased. All antinutritional factors such as phytic acid, tannin, trypsin inhibitor and hemagglutinin activity were decreased during soaking in 0.5% sodium bicarbonate. It was the same for the protein solubility in different solutions while the in-vitro protein digestibility and available lysine were increased.

Yongchao *et al.*, (2009) reported that the processing of douchi, a traditional chinese soybean-fermented food product, the pretreatments of soaking and cooking are directly affect the change in nutrient parameters and the production quality. Effect of soaking and cooking on fibrinolysis activity and amino nitrogen content of douchi was also studied. The soybean was cooked at 115oC for 10, 20, 30 min after soaking up to 10 h. The solid loss, including soluble protein, increased significantly with increase in soaking time. The hardness decreased significantly by increasing cooking time compare to increasing soaking time.

Elisa & Adelaide (2010) reported that the variation of phytate, calcium, zinc, and iron during soaking and cooking of soybeans. The phytate: Zn and phytate: Fe molar ratios were determined in order to estimate the bioavailability of these minerals. The water content of raw grains for all varieties was 9.9 g/100 g increasing to a range of 58.1-63.7 g/100 g after soaking and 63.1-66.0 g/100 g after cooking. Soaking caused a significant reduction in phytate 23- 30 % but cooking caused no additional reduction. The phytate: Zn molar ratio was 20 indicating that zinc absorption could be impaired, while the phytate: Fe molar ratio was 8 below the level of compromising absorption.

Munu *et al.*, (2016) reported that the effect of ambient temperature soaking time on soybean was studied for cold extraction of soymilk. Changes of hydration rate, grinding time, crude protein and solid recovery were parameters considered for seeds soaked for 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 hrs. Soybean hydration rate in ambient temperature showed a good fit (r = 0.9982) with Peleg's model. Raw soybean seeds chunk about 90% of water absorb to reach equilibrium in the first six hours of hydration. The increasing in moisture content from 12% to maximum of 147% in soaking time of 10 h. The water absorption increased 121% of the original weight of the soybeans after soaking for 10 h. The grinding time of the soybeans gradually decreased with soaking time for the first 6 hrs was 214 s and then increased gradually with each subsequent hour of soaking to reach 296 s after 39600 s of soaking. Both crude protein and total soluble solids generally increased gradually with soaking time from 0.91 to 1.48% and 0.867 to 1.67 % Brix respectively for the soaking time studied.

Aurelie *et al.,* (2017) reported that the effects of soaking and roasting on the physicochemical and pasting properties of soybean flour were evaluated. Raw soybean was soaked overnight in tap water for 0–72 hrs, dehull seeds, dried and roasted. Roasted and unroasted soy beans were ground and made flour use for experiment. The results reported that carbohydrates 22.8–27.9 g/100 g, the ash content 3.5–3.6 g/100 g and the polyphenols 0.29–0.51 g/100 g did not change during both the soaking and roasting processes. However, the proteins 35.8–46.0 g/100 g and lipid contents 21.4–29.5 g/100 g were significantly ($p < 0.05$) affected only in soaking process, with a decrease in total protein and an increase in lipid contents. Phytate content 0.22–0.26 g/100 g decreased significantly ($p < 0.05$) only in roasting process. The tannins 0.01–0.30 g/100 g and soluble proteins 4.0–29.0 g/100 g significantly ($p < 0.05$) diminished with both treatments. There was a significant increase in the least gelation concentration 20–30 g/100 m, a decrease in the swelling power 1.3–2.0 mL/mL and reduction in the viscosity (range peak viscosity 18–210 cP) of the flour slurry after soaking and roasting.

Humyra *et al.,* (2018) reported that the effects of soaking time and combination of soaking and grinding process hot or cold on phytate, lipoxygenase, urease, trypsin inhibitor activity, protein solubility and other nutrient contents were study. Soaking alone at 55 and 60^{o}C for different durations was found effective for the reduction of lipoxygense activity. Combination of soaking, blanching 80^{o}C for 10 min and hot grinding 100^{o}C significantly (P>0.05) reduced urease activity, more than 80% phytate activity and remove activity of trypsin inhibitor but did not affect protein solubility.

Zeruti (2019) reported that the effect of soaking temperature and time on proximate composition and sensory properties of soy products made from soybean. Use two types of water soaking temperatures hot water 40°C and ambient temperature water 25°C and three soaking times 8, 12 and 16 hrs were given in the experiment. The study show that soaking time and the temperature had significantly ($p<0.05$) affected proximate composition of soybean products. The protein content of flour was affected by soaking time and temperature. A value 44.26% was shown at 16 hrs soaking time with 40°C soaking temperature. The result was slightly greater than unsoaked soy flour 44%. The fat content of flour was 21.98 % for soybean soaked for 8 hrs at 40°C. This result was found to be high compare to raw or unsoaked soybean flour 20.80%. Higher fiber content flour 3.77 % was obtained for 16 hrs soaking time with 40°C. The fiber content increase with increasing soaking time at 40°C.

2.3 Recipe standardization

Nooraziah *et al.,* (2009) gives recipes for preparation of crackers. The crackers were prepared according to the developed method of (Manley, 2001). Formulation of the crackers such as Yeast was mixed with water (25°C) to form a suspension, to which the other ingredients weighed then added and kneaded to form smooth dough. Replacement of wheat flour with banana, pumpkin, mango pulp and mango peel flour were conducted based on 5% of the weight of the wheat flour. The dough was later proofed for 2 hours in a proofer, followed by sheeting to 1.0mm thickness using a dough sheeter. The dough was then cut into squares measuring 3cm x 3cm and 'docked' prior to baking at 170°C for 15 min.

Rahman *et al.,* (2013) studied that the procedure for crackers preparation, there were two different formulations of crackers biscuit such as formulation A and formulation B. The Formula A is designed for biological rising (used dry yeast) and Formula B is designed for chemical rising (not used dry yeast) crackers biscuits. Initially the stored raw materials quality was check out then the ingredients were mixed through mixture. The mixing temperature was 40°C and time was 10-12 minutes and the mixture speed was 40 rpm. Then the standing was performed for 60 minutes as the laying time exceeding 20 minutes is advised. After standing, forming was done and then sheeting was performed to make the thickness as 0.15 mm and then cutting operation was performed. Finally, the baking operation was conducted. In the baking zone, the oven has three sections, power type is direct hating system oven, and heat sources are top and bottom of the oven. Temperature in first zone was 180°C at top and at bottom 160°C. Temperature in second zone was 260°C at top and at bottom 240°C. Temperature in third zone was 140°C at top and at bottom 100°C. After baking, cooling of biscuit was done at 60% RH (Relative Humidity). After that the biscuits were wrapped and packed. The biscuits were stored at room condition temperature (25°C – 30°C) and relative humidity (58- 65%).

Zahra & Safaa (2015) reported that the recipes for crackers preparation, cracker samples were prepared in a straight dough process according to the recipe of commercial all purpose wheat flour (100% flour basis), sugar (2%), salt (2%), bakers' yeast (2%) and water (60–64%), depending upon the percent of HSR (Hibiscus subdariffa) in the formula. HSR was replaced wheat flour at varied amount as follows: 0%, 1.25%, 2.5%, 3.75% and 5% (i.e. if 5% HSR was added then the flour amount was reduced to 95%). Ingredients were mixed into cohesive dough, rolled into a consistent, thin sheet using a pasta roller and cut with rectangular mold into pieces after proofing. The crackers were baked in a forced-air convection oven at 210°C for 15 min. Baked samples were then cooled at ambient temperature, grounded in a standard coffee grinder to pass through a 40-mesh sieve, and stored in sealed bags in desiccators at room temperature.

Vaijapurkar *et al.,* (2015) reported that the biscuit was prepared after the flour preparation, following a standard formulation, with the addition of pomegranate peel powder. Dry ingredients like flour, soda and baking powder, pomegranate peel powder was mixed and sieved twice for uniform mixing of leavening agents to the flour and also other ingredients. Milk powder was mixed in small amount of water separately in a bowl. Ghee was taken in a bowl and heated until it melts. Then powdered sugar was added to the dry ingredient and mixed properly. Soft dough was prepared by addition of the melted ghee and then dissolved milk powder with sprinkling small quantity of water. Dough was rolled and then biscuits were cut into round shape. Biscuits was then kept in a baking oven for 20-30 min at 120-130°C for uniform baking.

Karad *et al.,* (2016) studied that the recipes refined wheat flour, Bengal gram flour, soya flour and other ingredients were weighed accurately. Then mix the weighed ingredients. Fat was added into the dry weighed ingredients. Water was added accurately to form dough. The dough was then kneaded and rolled to a uniform thickness. The crackers were cut out using round cutter. Then the crackers baking of crackers given at 140-180˚C for 15-20 minutes, cooled to ambient temperature and packed in high density polyethylene bags.

Kamal *et al*., (2016) studied that recipes, five types of cassava crackers were prepared using cassava flour, wheat flour, cassava starch and baking powder as given in the basic formulation. The ingredients were weighed accurately and mixed well with the addition of water. Mixture was given for 20 min for the preparation of dough. The dough was then rolled and prepare thin shit about 1-2mm. The rolled dough was cut into small pieces about $23×23×1mm^3$. The pieces were then subjected to direct steam for 20-30 minutes. After cooling steamed pieces were dried in an oven at 45°C for 14hr. All the dried samples were then fried in soybean oil at 130°C, 140°C and 150°C for 15 seconds, 13 seconds and 10 seconds respectively. After frying, the crackers were allowed to remove out excess oil. When the crackers were free from excess fat then add some salt for testing. The quantity of salt could be added depending upon the individual taste. After salting, the crackers were packed in high density polyethylene bags and stored at ambient condition.

Sachitra *et al*., (2017) reported that all the ingredients used for the snack crackers were prepared according to the procedure of (Han *et al*., 2010) with some changes. Quantity of the flour mix with of other ingredient and the dough was allowed to ferment room temperature for 16 to 19 hours. After fermentation, the sponge was added to the remaining ingredients and mixed for 3 to 7 minutes. After mixing, the dough was again fermented in troughs for 3 to 6 hours. The fermented dough was sheeted and laminated into 7 or 8 layers with a combined thickness of about 0.1 inches (2 mm). Circular crackers (diameter 4 cm) were cut from the dough sheet using a dough cutter and transferred onto a mesh-wired baking sheet. The dough was also docked, or stamped with pins, to form the pattern of holes. Baking is giving at about 160^0C for 20 minutes. After baking, the snack crackers were allowed to cool and packed in moisture-proof triple laminated Aluminum bags.

Venkatachalam & Nagarajan (2017) reported that the crackers made from wheat flour, green gram flour and the actual mixtures of wheat flour and green gram flour, were produced on a laboratory scale by a straight dough process, using a commercial cracker recipe with slight correct changes. The ingredients, namely flour mixture, sugar (2%), salt (2%), chemical leavening agent (sodium bicarbonate, 2%), vegetable oil (10%) and water (15%) were thoroughly mixed together to form a cohesive dough using an electric at low (80 rpm, 1 min) and moderate speeds (100 rpm, 10 min). The dough was wrapped in polyethylene film and was allowed to sit for 10 min under refrigerated temperature and then for 20 min at room temperature. After leaving to sit, the dough was sheeted to 5 mm thickness using a pasta roller, and cut into 4 cm squares with a mold. These molded crackers were baked in a double deck infrared conventional oven at 180ºC for 11min and were pulled out of the oven to apply the flavoring agent. For savory flavor, finely chopped garlic was mixed with honey and brushed on the crackers, after which the baking continued for another 4 min at 180ºC, before cooling down to room temperature.

Shere *et al.,* (2018) reported that the recipes, all the ingredients were weighed accurately according to the formulation. Mix refined wheat flour, oil, dissolved yeast and other ingredients to form dough of firm consistency. The dough was placed for 60 min in refrigerator. After resting period dough is rolled to uniform thickness of 1.5 – 2.0 mm and crackers were cut using round cutter. Then crackers were baked at 180◦C for 10 to 15 minutes, cooled to room temperature and packed in high density polyethylene bags.

Tahiya *et al.,* (2018) studied on preparation method of crackers. Dry ingredients were mixed in a mixer, whilst the liquid ingredients were mixed separately to form emulsion. Proportion of salt (1g/100 g) was kept constant for each treatment. The emulsion was incorporated into the dry ingredients and mixing was done through high-speed mixer. Dough was wrapped in polythene bags and left at room temperature for 30 min to ensure uniform distribution of liquid. Dough sheeting was done manually to a thickness of 2.5 mm and press mould was used to cut sheets to a width of 35 mm. Baking was done in double-deck baking oven at 170°C for 10 min. After cooling for 5 min at room temperature, the crackers were wrapped in plastic pouches and kept at room temperature for further study.

Reddy *et al.,* (2019) reported the recipes for preparation of crackers "Sponge and Dough" method is used. There are two stages in this method (a) Preparation of sponge (b) preparation of dough. For sponge, Yeast is activated by using warm water and sugar which acts as food for yeast to grow and allow it to rest. Add this starter culture to 50% of sorghum and refined wheat flour and knead it to smooth dough with required water. Keep it aside in warm condition for the fermentation to occur. For dough, the sponge is added to the remaining ingredients like sorghum flour, butter, ammonium bicarbonate, basil powder salt, sugar mixed and formed into dough and make it for second fermentation. The fermented dough is sheeted to the thickness of about 1mm and cut into circular shape by using a mould, butter is greased and salt is sprinkled on the surface then docking is done. Baking was done at 150°C for 10-12 minutes. The baked crackers are cooled to room temperature and packed in metalized polyethylene pouches.

Daniel *et al.,* (2019) reported that the recipes, yeast crackers were formulated based on a rice and tef flour mixtures. Dough samples were prepared by mixing 100 g of flour mixture, with 20 g of olive oil, 10 g of sugar, 3 g of salt, and 2 g of hydroxypropyl methyl cellulose. Water was added last, while mixing flour. After kneading, the dough was put for fermentation at 18°C for 24 h. After fermentation, the dough was laminated to ~2.5 mm, and cut into 3.5 mm-side square pieces. Each batch was baked in a forced-air convection oven at 165°C for 25 min. The crackers were allowed to cool at room temperature for 1 h before being placed in sealed polyethylene bags for further analyses.

Gavhane & Ghodke, (2019) reported that the recipes on preparation of crackers ingredient used like Refined Wheat flour, Whole Wheat flour and Amaranth Leaves powder. All Ingredients mixed together to make a smooth dough, rolling than cutting had done and put it for baking at 175°C for 15-20min.

2.4 Proximate analysis of cracker

Kamal *et al*., (2016) studied chemical compositions of fried cassava crackers are given that variation in moisture content of the fried crackers was observed with a range from 2.67 to 3.01% with S_1 sample having lowest and S_2 sample having highest moisture. A significant ($p<0.05$) difference in ash content of fried crackers was observed in this study. Highest ash content (2.05%) was found in S_3 sample, whereas S_5 sample contained lowest ash (1.68%). Protein content in fried cassava differed significantly ($p<0.05$) in this study. Highest (11.13%) and lowest (9.58%) protein were resulted in S_4 and S_2 samples respectively. Significant ($p<0.05$) difference in fat content of fried cassava samples were also observed in this study. Fat content ranged from 19.73 to 21.95% being highest for S_3 sample and lowest for S_4 sample. Variation may be due to frying technique, and varietal change of cassava root. Sugar content of fried cassava chips differed from 3.87 to 4.41%. It is interesting that no scientific report is available regarding sugar content of fried cassava cracker. Data shows that a range of carbohydrate 59.23-60.98% was resulted in fried cassava crackers.

Karad *et al.,* (2016) studied the proximate analysis of methi crackers are reported, Crackers are dried product, it expected to low moisture content the sample C content

3.7% moisture and it is low as compared to another sample i.e. 3.9% and 4%. From the result, ash content ranged between 0.35-0.45 %. From the result sample C content higher protein than the other sample i.e. 9.81%. The fat content in methi crackers ranged between 29.2-32.5%. Sample C contain low fat so it is desirable. High fat gives rancidity in food leading to development of unpleasant and odorous compound. Carbohydrate content ranged between 50.4-55.2%. The sugar content of sample C is 3.06% and the other sample content sugar 4.9 - 5.10% respectively.

Sachitra *et al*., (2017) reported that the proximate composition of all-purpose wheat flour and defatted coconut flour are stated. It was found that had a defatted coconut flour significantly higher content of protein (22.10%), fat (8.04%), ash (6.17%), crude fiber (17.69%) and lower content of carbohydrate (41.06%) and moisture (10.66%) in comparison to all purpose wheat flour. On the other hand, all-purpose wheat flour contained lower content of protein (9.57%), fat (0.79%), ash (0.49%), crude fiber (0.51%) and higher content of carbohydrate (77.98%). Functional properties of the defatted coconut flour significant differences compared to all-purpose wheat flour. As a hydration parameter of the flour, the water holding capacity of defatted coconut flour was significantly higher than that of wheat flour ($p \leq 0.05$). The value of the bulking density and the oil retention capacity of defatted coconut flour was significantly higher than those of wheat flour ($p<0.05$).

Udaybeer *et al.*, (2018) reported that the nutrient content of the pearl millet baked cookies are given, The pearl millet baked in cookies (C_2) had highest contents moisture (4.32%), protein (11.98%), fat (18.20%), carbohydrate (65.58%), ash (1.22%) and crude fiber (.30%) content than control. Highly significant difference was noted for moisture, carbohydrate**,** crude fiber, fat, ash and protein content at 5% level (P=0.05) in treatment.

Herath *et al.,* (2018) reported that the proximate composition of for crackers which made from different compositions of multi-grain flours is compared with the proximate composition of 100% wheat cracker. In the nutritional point of view ash, fat, protein and dietary fiber contents of crackers are increased with the use of composite flour than the wheat cracker. The moisture content of formulated crackers was lower than 4% i.e. the maximum moisture content that can be present in cracker 35. The lower moisture content will increase the shelf life of the product. The highest total dietary fiber content was in

20% chick pea added cracker at 40% level of replacement. Protein and fat contents of soybean incorporated cracker were the highest amounts which showed significantly different ($P<0.05$) from wheat cracker.

Reddy *et al.,* (2019) reported that the nutritional status is increased by developing crackers with sorghum flour and basil leaves powder. Average carbohydrate content in regular crackers is 72- 78% but in this variation it is 58% (snack crackers). The crackers develpoed with sorghum flour contains 7.25% protein than other two variants ranging from 4-6%. The fat content in the cracker's ranges from 9- 10 % in the 3 variants. The fat used also adds to the fat percentage variation. Ash indicates minerals such as mineral content and leavening agents (chemical leavening agents) used. General saltine and snack crackers averaged about 3% ash. Sorghum crackers contain about 1.2 - 1.6% ash content. Crackers contain less moisture compared to other baked products. Snack crackers are fermented, proofed and baked. During baking maximum amount of moisture is evaporated hence, crackers are light, crunchy with low moisture content. Sorghum crackers contain about 2.5- 3.9% moisture, which helps to store for long duration.

2.5 Sensory evaluation of the crackers

Manaois *et al.,* (2013) studied on sensory evaluation gives results show that *malunggay* can be used in the development of nutrient-enriched rice crackers with good storage quality and high consumer acceptability. In which rice crackers prepared with different levels of moringa. All moringa-supplemented samples were generally green, even at 1% incorporation. Moringa powder used in wheat breads also significantly changed the color of the product at the same supplementation level.

Omoba *et al.,* (2015) studied on sensory analysis given that the biscuits were indistinguishable from a whole grain wheat biscuit standard in terms of hardness, roughness and coarseness but they were darker, less crisp, less dry and denser with distinctive sorghum flavor. Biscuits containing sourdough were sourer to taste and had more aroma and a more fermented taste and odor character such as more rancid and bitter with less sorghum-type flavor.

Zahra & safaa (2015) reported that in sensory evaluation acceptable crackers with pleasant flavor were obtained by incorporating up to 3.75 % Hibiscus sabdariffa calyxes residue into the cracker's formula. Crackers prepared with 5% Hibiscus sabdariffa residue received the less sensory rating compared to nonless Hibiscus sabdariffa enriched cracker.

Vaijapurkar *et al.,* (2015) reported that the results of sensory evaluation of biscuits prepared with 40, 50 and 60 % of pearl millet flour i.e. WB_1, WB_2 and WB_3 were reported. It was found that replacement nearby 50% of wheat flour by pearl millet was most acceptable by the trained sensory panel. Data revealed that the overall acceptability of Sample WB_2 and Sample WB_1 was 7.9 and 7.7. It was found that replacement of 60% wheat flour by pearl millet was not accept by sensory panel because the appearance of the pearl millet biscuits was affected i.e. darker in color and bitter in taste and also found cracks in texture of biscuits. Hence, in the present investigation pearl millet flour can be incorporated nearby 50% was found most acceptable as a standardized recipe.

Akonor (2016) reported that crackers produced from high-quality cassava flour, cassava starch, and prawn powder was optimized based on sensory evaluation. Ten different formulations of crackers were produced using mixture design. A mean score of 4.7, 5.6, 5.2, and 5.2 was obtained correspondingly for taste, crispiness, puffiness and acceptability. Scores for these attributes indicated that the crackers were acceptable.

Kamal *et al.,* (2016) studied on sensory evaluation gives that significant ($p<0.05$) difference in sensory attributes was observed and S_5 sample (cassava flour: wheat flour: baking powder= 67:30:3) was most accepted cassava crackers to panelists. Results of this study examine that cassava root has good potential in the production of various snacks especially crackers.

Herath *et al.,* (2018) studied on the sensory evaluation of crackers, the mean ranks for crispiness, appearance, color, flavor, creaminess, mouth feel and overall acceptability in sensory evaluation obtained by F_1 were not significantly different from ranks obtained by the wheat cracker ($p>0.05$). In cracker formulation, 40% of mixed-grain was the optimum level substitution and the cracker thus formulated with 1:1:2 ratio in brown rice: finger millet: chick pea was the best formulation.

Daniel *et al.,* (2019) reported that the result of the incorporation of tef flour to rice-based crackers was examine by using sensory panel. The formulations with higher antioxidant activities were selected (50 % and 100 % white, brown and mixture tef) and were compared to control cracker. The panel evaluated samples according to the texture, flavor, after taste, mastic ability and preference.

Alibasic *et al.,* (2020) reported that sensory analysis of the given properties of crackers shows that the best quality was achieved with crackers of 20% buckwheat flour as well as with crackers with 10% buckwheat sourdough which were show that a product of very good quality.

2.6 Microbial study of crackers

Manaois *et al.*, (2013) reported that the microbial study, the total plate count of the samples also significantly increased on the third week, but microbial counts were within acceptable limits <10 x 104 cfu/g and <1,000 cfu/g for total plate count and molds respectively. No coliform was detected in all samples until the end of the storage period. These results show that both forms dried or fresh of moringa added at the specified levels can be used to prepare shelf stable nutrient-enriched rice crackers.

Athawale *et al.,* (2015) reported that the microbial studies such as microbial load obtained were under the acceptable limits for a period of 3 months from the date of manufacture. Bacterial count for the crackers was lower than the acceptable limit of 1×105 cfu/g of sample. The bacterial count for the fresh, 30 days 60 days and 90 days obtained were 1×102 cfu/g, 2.51×103 cfu/g, 7.5×103 cfu/g and 6.4×104 cfu/g. Fungus growth was not shown in all the cases.

Sachitra *et al.*, (2017) reported that the shelf-life studies carried out once in two weeks for a period of three months after packing in triple laminated aluminum foil and stored under ambient conditions. Analysis of aerobic colony count was done by incubating microorganisms in nutrient agar medium at 37°C for 48 hours and the yeast and mould count was done by incubating in potato dextrose agar medium with 0.01% chloramphenicol held at room temperature.

Oladipo *et al.*, (2019) reported that the microbial analysis gives such as the total viable counts of the samples ranged from 0.2x104 cfu/g to 2.8x104 cfu/g. Also, the total enterobacteriaceae counts ranged from 0.2x104 cfu/g to 5.3 x104cfu/g. Bacterial pathogens were isolated from the samples and the isolates were characterized and identified to be *Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Bacillus* *subtilis* and *Proteus vulgaris*. *Bacillus subtilis* was found to be the most occurring bacteria species in both the flour and the biscuit samples

2.7 Textural study of crackers

Singh *et al.,* (1996) stated that hardness of cookies is caused by the interaction of protein and starch by hydrogen bonding. Increase hardness in biscuits with increasing levels of defatted soybean flour up to 50 per cent.

Paul *et al.,* (2014) reported that the addition of different proportions of amaranth seeds flour and watermelon seeds flour affect the texture of the prepared product, the texture becomes crunchy and more acceptable as the amount of amaranth seeds flour and watermelon seeds flour increases.

Vaijapurkar *et al.,* (2015) reported that the analysis of variance of the texture revealed that there was significant effect on texture of the biscuits when bajara flour added. The result shows that the texture profile of bajara biscuits is higher in sample first. There was a decrease in the quality score for the texture of the biscuits with an increase in the bajara flour addition.

Udaybeer *et al.,* (2017) reported that the average peak force is the measure of cookies hardness. It was observed that there was significant increase in hardness of cookies from 3.76 to 15.97 N with increasing levels of pearl millet flour in cookies. The increased hardness may be attributed to dilution of wheat proteins with pearl millet proteins. The interaction of pearl millet proteins with wheat proteins made cookies compact, thus increasing the hardness.

Kulthe *et al*., (2017) reported that the hardness, breaking strength and cutting strength of cookies were increased with the incorporation of pearl millet flour in cookies. Each cookie was placed on the loading cell and compressed as per the standard procedures. Increase hardness in biscuits with increasing levels of defatted soybean flour up to 50 percent.

Shere *et al.,* (2018) reported that the textural analysis such as the texture of product was greatly improved with progressive increase in beetroot pulp. The sample showed maximum at 15% beetroot pulp addition level. Hence higher level of beetroot pulp had no adverse effect on the texture. The improvement in textural qualities of cracker can be attributed to fiber & starch molecule interaction providing firmness to the matrix.

2.8 Packaging material study of crackers

Ubonrat (2009) reported that two varieties of rice crackers RC-1 and RC-2 were packaged in two types of packaging materials, polyethylene and polypropylene pouches and stored at 30C/75% RH and 30C/85% RH to provide actual storage conditions and determine shelf-life.

Lixinlu and Fangxu (2009) reported that the influences of intensity of ultraviolet light, light-barrier property of packaging film on the fat photo-oxidation and accelerated shelf life of cookies were studied. Unpacked cookies were stored at a temperature of 408 °C and a relative humidity of 50% for 10 to 65 days with an intensity of the UV light of 0.3, 1.9 and 9.5 mW/cm^2. The same batch of cookies was packed with oriented nylon polyethylene, polyethylene terephthalate-oriented nylon polyethylene and bi-oriented polypropylene vacuuming aluminized casting polypropylene and stored at the same temperature and RH and UV-light intensity of 1.9 mW/cm^2 for more than 40 days. The peroxide values (POV) of cookies were measured under the storage conditions.

Robertson (2011) reported that the properties of the most important materials used to package biscuits plastics and paper are given and main aspects of this packaging and its influence on the storage life of biscuits, crackers and cookies is studied. Hint of failure are discussed and the shelf life of biscuits calculate that spoil by moisture gain and oxidation are given and the importance of the surface area to volume ratio of the package is given.

Dar (2012) reported that packaging material had significant impact on biscuit quality. The biscuits were stored safely in both packaging material such as high-density polyethylene and laminate microbiological study depicted that microbial count was far below the permissible limit up to 3 months of storage of biscuit in HDPE and laminate at room temperatures.

Santina *et al.,* (2014) studied that the effect of innovative multilayer packaging materials as compare to standard one on biscuit quality was reported during storage at 25, 35, 45°C and 50% RH for 92 days. Three different packaging materials were used metalized Orientated Poly Propylene paper as control, metalized Poly-Lactic Acid paper, metalized Orientated Poly Propylene with Ethylene Vinyl Acetate Pro-Oxidant Additive paper. Ethylene Vinyl Acetate Pro-Oxidant Additive is used to make the plastic layer biodegradable. Various quality sample parameters moisture, water activity, texture, peroxide value, hexanal were analyzed during storage.

Baele *et al.,* (2021) reported that alternative packaging concepts for two dry shelf-stable food products were evaluated. Whole milk powder was packaged in unsealed Polyethylene bags as a control, representing a typical paper bag with a PE liner that is stapled shut without a seal. Alternative packages were sealed PE bags (OTR 1464 cc/m^2/d, WVTR3 g/m^2/d), PE/PA/EVOH/PA/PE (OTR 0.25 cc/m^2/d, WVTR 0.95 g/m^2/d) and PA/EVOH/PA/PE (OTR 1.24 cc/m^2/d, WVTR 8 g/m^2/d) multilayer bags, and PP/Al/PE (OTR 0.1 cc/m^2/d, WVTR 0.1 g/m^2/d) bags and stored at room temperature and relative humidity between 70% and 90%.

CHAPTER – III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHOD

The present experimental desing with given title " Studies on development of pearl millet crackers incorporated with sorghum and soybean flour" was carried out in department of food chemistry and nutrition with the collaboration of department of food proccesing technology, department of food microbiology and Safety, Department of Food Engineering, collage of food technology, department of soil science and collage of agriculture VNMKV, parbhani during the year 2019-21.

This chapter deals with the experimental techniques and procedures adopted to carry out the experiments towards fulfilling the various objectives of this investigation

3.1 Raw Materials

The selected food grains such as pearl millet (varieties parbhani sampda), sorghum varieties parbhani motti) , soybean (varieties anusaya), milk and sugar were procured from the local market of Parbhani.

3.2 Chemicals and Reagents

Most often chemicals and standard reagents (analytical grade) utilized in this experimental design were analytical grade which was obtained from the Department of Food Chemistry and Nutrition, Department of Food Proccesing Technology, Department of Food Microbiology and Safety, Department of Food Engineering and College of Food Technology, VNMKV, Parbhani.

3.3 Processing and Analytical Equipment's

The processing and analytical equipment are included Hot air oven, soxhlet apparatus, micro kjeldahl, muffle furnace, brookfield viscometer, vernier caliper, grinder, electronic weighing balance, spectrophotometer, laminar airflow cabinet, and glassware were used from Department of Food Chemistry and Nutrition, Department of Food Engineering, Department of Food Microbiology and Safety and Department of Food Process Technology, Niche area laboratory, Bakery unit and College of Food Technology, VNMKV, Parbhani.

3.4 Packaging material

Suitable packaging material such as high density polyethelene bags and aluminate standing pouches for safe storage of products were procured from the local market of parbhani.

3.5.1 Physical properties of selected Pearl millet, Sorghum and Soybean

3.5.1.1 Thousand kernel weight

Thousand kernel weight was calculated by counting 100 randomly elected grains and weighing them on an electronic weighing balance having an accuracy of 0.001 g and then multiply it by 10 to give a mass of 1000 seeds.

3.5.1.2 Bulk density (ρb)

25 g of sound grains will be weighed on the digital weighing balance and filled into the measuring cylinder earlier filled with a reference solution of kerosene or toluene. The increase in the level of liquid will be measured after adding the grains. It is bulk density represented in g/ml (Dutta *et al.,* 1988).

$$\text{Bulk density } (\rho b) = \frac{\text{Weight of seed}}{\text{Volume of seeds}} \times 100$$

3.5.1.3 True density (ρt)

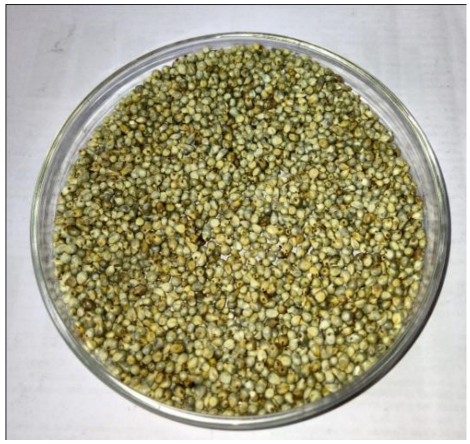
25 g of grains will be filled into the measuring cylinder and volume occupied by them will be measured. It will be then calculated by the following formula and represented in g/ml (Rooney *et al.,* 1980).

$$\text{Treue density} = \frac{\text{Weight of grain}}{\text{Volume of grains}} \times 100$$

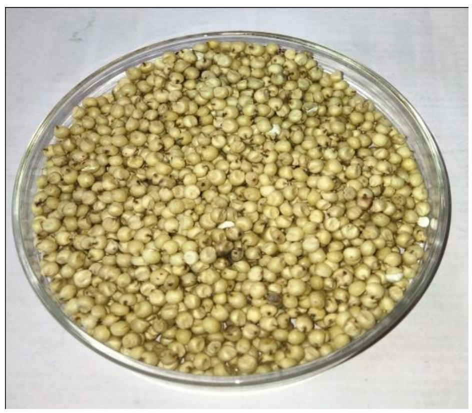
3.5.1.4 Angle of repose

The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the grain mass to a horizontal plane when material is free falling or sliding. It was determined by making a circular pile of the grains freely falling. The height of pile was taken (h) and its radius (r) was also taken. Angle of repose was then calculated by following formula.

$$\text{Angle of Repose } (\theta) = \tan^{-1}(h/r)$$



Pearl millet



Sorghum

Soybean

Plate 3.1: Raw materials required for preparation of crackers

3.5.1.5 Porosity (ε)

The porosity (ε) of the bulk grain was defined as the fractions of the space in the bulk grain that is not occupied by the grain. The porosity, ε was calculated using formula

$$\varepsilon = (1 - \rho b) \times 100 / \rho b$$

Where, ρb and ρt are the bulk and true density, respectively in kg/m^3

3.5.2 Physical properties of prepared product

Physical properties of the crackers were determined as described by (Baljeet *et al.*, 2010).

3.5.2.1 Weight (g)

Measured by means of a digital measuring balance as average values of four individual snack crackers.

3.5.2.2 Width (cm)

Six pearl millet crackers were placed edge to edge, their total width was measured and average width was determined by taking mean value (AACC, 1983).

3.5.2.3 Thickness (cm)

The average thickness of pearl millet crackers was measured by placing six biscuits one on top of another and measuring their height and taking average.

3.5.2.4 Spread factor (%)

Spread factor was obtained with the help of following formula

SF = (width/thickness) × 10 (AACC, 1983).

3.5.2.5 Puffiness (%)

Puffiness of crackers was obtained with the help of following formula.

$$\text{Puffiness (\%)} = \frac{\text{Thickness of baked cracker} - \text{Thickness of cracker dough}}{\text{Thickness of cracker dough}} \times 100$$

3.6 Proximate analysis

3.6.1 Determination of moisture content

Moisture was estimated by accurately weighing the 5 g sample, it was ground and subjected to oven drying at 105°C for 4 hr. It was again weighed after cooling in desiccators until constant weight. The resultant loss in weight was calculated as moisture content (AOAC, 1990).

$$\% \text{ Moisture} = \frac{\text{Initial weight} - \text{final weight}}{\text{Total weight of sample}} \times 100$$

3.6.2 Determination of Crude Fat

The 5g ground sample was weighed accurately in thimble and partially defatted with petroleum ether in Soxhlet apparatus for 6-8 hrs at 60°C. The resultant ether extract was evaporated and lipid content was calculated (AOAC, 1990).

$$(\%) \text{ Crude fat} = \frac{\text{Final weight of flask} - \text{Empty weight of flask}}{\text{Weight of sample}} \times 100$$

3.6.3 Determination of crude protein

Protein content was determined by Micro-kjeldahl method using 200 mg of sample by digesting the same with concentrated sulphuric acid containing 1 g of catalyst mixture for 2-3 hr at 100^{o} C. Then it was distilled with 40% NaOH and liberated ammonia was trapped in 4% boric acid and then it was titrated against 0.01N H_2SO_4 using mixed indicator (Methyl red: Bromocrysol green1: 5) Then % Nitrogen was calculated by formula and % protein was estimated in sample by multiplying with factor 6.25 (AOAC, 1990).

$$\% N = \frac{(\text{Sample-blank}) \times \text{Normality of } H_2SO_4 \times \text{Vol. made for distillation} \times 0.014 \times 100}{\text{Aliquot taken for distillation (ml)} \times \text{Weight of sample (g)}}$$

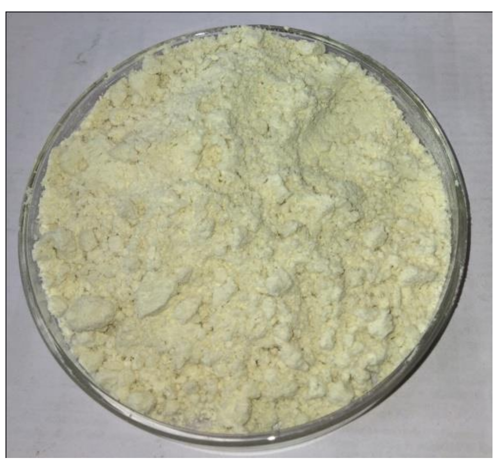
Total Protein = % Nitrogen X 6.25

3.6.4 Determination of Ash

5 g sample was weighed into silica crucible and heated at low flame till all the material was completely charred and cooled. Then it was kept in muffle furnace for about 4 hr at 550°C. It was again cooled in desiccator and weighed and repeated until two consecutive weights were constant. The per cent ash was calculated by knowing the difference between the initial and final weight (AOAC, 1990).

Pearl millet flour

Sorghum flour



Soybean flour

Plate 3.2: Flour used for preparation of crackers.

$$\% \text{ Ash} = \frac{\text{Weight of crucible with ash} - \text{weight of empty crucible}}{\text{Total weight of sample}} \times 100$$

3.6.5 Determination of Crude Fiber

About 2 to 5 g of moisture and fat free samples were weighed into 500 ml beaker and 200 ml boiling 0.255 N (1.25 w/v) $H2SO_4$ was added. The mixture was boiled for 30 minutes keeping the volume constant by addition of water at frequent intervals. At the end of this period, the mixture was filtered through a filter paper and the residue washed with hot water till free from acid. The material then transferred to the same beaker and 200 ml of boiling 0.313 N NaOH solution added. After boiling for 30 minutes the mixture was filtered through filter paper. The residue was washed with hot water till free from alkali followed with some alcohol. It was then transferred to crucible dried overnight at 80-1000C and weighed. The crucible was heated in a muffle furnace at 550-6000C for 4 hours cooled and weighed again. The difference in the weights represented the weight of the crude fiber (AOAC, 1990).

$$(\%) \text{ Crude fibre} = \frac{\text{Weight of residue} - \text{Weight of ash}}{\text{Weight of sample}} \times 100$$

3.6.6 Total Carbohydrates

Carbohydrate were calculated by difference method as follows (AOAC 2005)

Carbohydrate = 100 – % (moisture + fat + protein + crude fiber + ash)

3.7 Estimation of minerals

Minerals like calcium, magnesium, potassium, zinc, copper, sodium and iron were determined by using titration and spectrophotometric method (Atomic Absorption Spectrophotometer).

3.7.1 Mineral solution preparation

The ash obtained was moistened with glass distilled water (0.5-1 ml) and concentrated HCl was added and evaporated to dryness on a boiling water bath. Again 5 ml concentrated HCl was added and evaporated to dryness as before. Lastly, 4 ml of HCl and 5 ml of distilled water were added.

This solution was warmed over a boiling water bath and filtered into the 100 ml volumetric flask using Whatman no.4 filter paper. After cooling the volume was made to 100 ml using distilled water and a suitable aliquot was used for the estimation of calcium and iron.

3.7.2 Determination of Calcium

Reagents

1) Ammonium oxalate
2) Conc. ammonia solution (25 % v/v)
3) Methyl red indicator
4) Sulphuric acid (2N)
5) N/100 $KMNO_4$ solution

25 ml mineral solution was diluted to 150 ml with distilled water and neutralized with ammonia solution using methyl red as an indicator till pink color changes to yellow. Further, the solution was boiled and 10 ml of 6 per cent ammonium oxalate was added. This mixture was boiled for a few minutes and added with conc. glacial acetic acid (99.5 percent) until the color was distinctly pink. The mixture was kept aside in warm place (overnight) and when precipitate settled down, the supernatant was tested with a drop of ammonium oxalate to ensure the completion of precipitation. Thecontents were filtered through Whatman no.4 filter paper and given washings of warm distilled water. The precipitate was transferred to a beaker by making a hole in the center of filter paper and by giving washings of sulphuric acid (2N, 5ml) twice. Then the solution was heated to 70 ºC and titrated against N/100 $KMNO_4$. Simultaneously a blank was also run. The results were expressed as mg calcium/100g sample (Ranganna, 1986).

Formula: 1ml of 0.01N $KMnO_4$ = 0.2004 mg Calcium

3.7.3 Determination of Iron

Iron content was determined by a-a, dipyridyl method described in AOAC (2005) exactly 10 ml of wet digested sample solution was pipetted into a volumetric flask of 25 ml capacity in triplicates. 1ml of hydroxylamine hydrochloride solution, 5 ml of acetate buffer solution and 2 ml of a-a, dipyridly solution were added into each volumetric flask. The volume was made up to 25 ml with glass distilled water

Plate 3.3: Stable Micro System TA-XT2 plus Analyzer

Plate 3.4: Atomic Absorption Spectrophotometer

and the content was mixed will. The intensity of the color developed was read in Spectronic 20 at 510 nm. The iron content of the digested sample solution was read from the standard curve of known concentration of iron.

Preparation of standard curve

Pipette 0.0, 0.5, 1.0, 1.5, 2.0, 3.0 and 4.0 ml of Fe standard solution into a series of 25 ml volumetric flasks and add to each of them exactly 0.2 ml of conc. HCl. Dilute each of them to exactly 10 ml with water and then add reagents in the same way as for the sample, Plot the quantity of Fe (in mg) against the absorbance (I.C.M.R, 1990).

Iron content of sample

$$(\text{mg Fe / 100 g sample}) = \frac{\text{Quanrtity of Fe in an aliquote of ash solution (from caliberation curve)}}{\text{An aliquote of ash solution taken for determination}} \times \frac{\text{Total volume of ash solution}}{\text{Wt of the sample taken for ashing}} \times 100$$

3.7.4 Determination of Magnesium

Magnesium was estimated by the colorimetric method. Measure 10 ml of ash solution into a 15 ml graduated centrifuge tube. Add 1 drop of methyl red indicator. Neutralize the solution with NH_4OH and ammonium oxalate and make the solution to a volume of 13 ml. Mix and allow to stand overnight. Centrifuge for 10 min. and discard precipitate. Measure 1 ml of the supernatant liquid from above into a 15 ml centrifuge tube. Add 3 ml of water, 1 ml of ammonium phosphate and 2 ml of NH_4OH. Mix and allow standing overnight. Centrifusge for 7 min discard the supernatant liquid mix with 5 ml of dilute NH_4OH centrifuge for 7 min and discard supernatant liquid. Dry the precipitate by placing the tube to the container of hot water. Add 1 ml of dilute HCl and 5 ml of water to dissolve the precipitate. Add 1 ml of the molybdic acid solution, 0.5 ml hydroquinone, and 0.5 ml sodium sulfite solution. Mix and allow to stand for 30 min. Transfer the solution to the colorimeter tube and read the absorbance in a colorimeter using a No. 66 red filter. Set the instrument scale at zero with scale (Ranganna, 1986).

3.7.5 Determination of Potassium

It was determined by using a flame photometric technique. The sample for potassium estimation was digested using $HClO_4$ and HNO_3. The 0.5 g sample was taken. In that 5 ml HNO_3 was added and kept overnight. The next day again 5 ml HNO_3 was added and sample digested by boiling on a gas burner. Boiling continued till color changes to colorless. The volume digested made 100 ml by adding distilled water and potassium was estimated by a flame photometer (Ranganna, 1986).

3.8 Determination of antinutrients in soybean

3.8.1 Tannin content

Tannin content was determined by colorimetric method using Folin-Denis reagent (Schanderi 1970).

Reagents

1. Folin-Denis reagent: The reagent was prepared by mixing 100 g of sodium tungstate, 20 g of phosphomolybdic acid and 50 ml of 85 per cent orthophosphoric acid. The mixture diluted to about 750 ml with distilled water. It was reflux for 2 hour, cooled to 25 °C and diluted to 1000 ml with distilled water.

2. Alkaline reagent: 35 g of anhydrous sodium carbonate was added to 100 ml distilled water and heated to 80°C. It was allowed to cool overnight and decanted to obtain clear liquid.

3. Standard tannic acid: 100 mg of tannic acid was dissolve in distilled water and volume made to 1000 ml. This solution contained 100 µg tannic acid/ml.

Procedure

Preparation of standard curve

Different concentrations of standard tannic acid solution (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2 and 1.4 ml) were taken in triplicate in 100 ml volumetric flasks. The volume in each flask was adjusted to 2.0 ml with distilled water. To this, 5 ml Folin-Denis reagent was added, followed by addition of 10 ml of alkaline reagent. The flasks were shaken well and volume made to 100 ml with distilled water. After 30 min, the colour intensity was measured at 700 nm. A graph of tannic acid concentration vs. absorbance was plotted.

Tannins in the sample

Tannins in the sample was determined in same way as described under standard curve by using 1 ml of sample instead of the standard tannic acid. Results were expressed as milligrams of tannic acid per 100 ml of sample.

3.8.2. Phytic acid content

Phytic acid was determined by standard procedure of (Wheeler & Ferrel 1971).

Reagents

1. 3 per cent (w/v) Trichloroacetic acid (TCA): Three g of trichloroacetic acid was dissolved in 100 ml distilled water.
2. Iron solution: Ferric chloride (290 mg) was dissolved in 50 ml of 3 per cent TCA.
3. NaOH (0.5 M): Sodium hydroxide (2 g) was dissolved in distilled water and the volume made to 100 ml.
4. HCl (0.5 M): Concen. Hydrochloric acid (4.22 ml) was diluted to 100 ml with distilled water.
5. O-Phenanthroline (0.05 per cent, w/v): O-Phenanthroline (50 mg) was dissolved in 100 ml of distilled water.
6. P-Hydroxyquinone (0.2 per cent, w/v): P-Hydroxyquinone (0.2 g) was dissolved in 100 ml of distilled water.
7. Sodium citrate (25 per cent, w/v): Sodium citrate (25 g) was dissolved in 100 ml of distilled water.

Procedure

Two g of the sample was extracted with 40 ml of 3 per cent TCA by shaking for 30 min. The suspension was centrifuged at 9000 rpm for 10 min. The iron solution (0.6 ml) was added to 5 ml supernatant extract and heated for 45 min. The contents of the tubes were cooled and centrifuged for 15 min at 12000 rpm. The precipitate was washed three times with TCA solution and once with water. Each time precipitate was washed with 5 ml TCA, heated for 10 min and then centrifuged at 15000 rpm for 10 min. The precipitate was mixed with 6 ml of NaOH, heated for 30 min and centrifuged for 15 min at 21000 rpm. The $Fe(OH)_3$ formed was dissolved in 10 ml HCl with heating for 10 min. The resulting $FeCl_3$ solution was diluted to 100 ml with distilled water. 3 ml of aliquot was taken and 5 ml each of O-phenanthroline and P-hydroquinone were added, followed by the addition of 0.15 ml of sodium citrate solution and mixed thoroughly. The absorbance was read at 510 nm after 5 min. The phytate-P was calculated from the standard curve of $FeCl_3$, $6H_2O$ diluted with 0.5 M HCl to prevent $Fe(OH)_3$ formation and expressed as mg/g of sample.

3.8.3 Trypsin inhibitor content

Trypsin inhibitor content in soybean was determined by procedure elaborated by Kakade *et al.,* (1974).

Trypsin solution

In 200 ml 0.001 M HCL was dissolved in 4 mg of accurately weighed trypsin. The prepared solution can be stored in the refrigerator for 2 to 3 weeks without appreciable loss in activity.

Substrate solution

40 milligrams of benzoyl-D L arginine-p-nitroanilide (BAPA) hydrochloride was dissolved in 1 ml of dimethyl sulphoxide and diluted to 100 ml with triss-buffer prewarmed to 37 °C.

Preparation of soybean sample

One gram of finely ground sample (100 mesh) was extracted with 50 ml of 0.01 N NaOH.

Procedure

Portion (0, 0.6, 1.0, 1.4 and 1.8) of soybean suspension were pipetted into duplicate sets of test tubes and adjusted to 2.0 ml with water. After that 2 ml of trypsin solution was added to each test tube and tubes were placed in a water bath at 37 °C. To each tube 5 ml of benzoyl-D L arginine-p-nitroanilide (BAPA) hydrochloride solution previously warmed to 37 °C was added, exactly 10 min later the reaction was terminated by adding 1 ml of 30% acetic acid. After through mixing, the contents of each tube was filtered (Whatman No. 3) and the absorbance of the filtrate was measured at 410 nm against a reagent blank. The inhibitor content was calculated from the deferential absorbance readings and reported in pure or absolute units as mg of trypsin inhibitor/g of sample by using the following formula derived by (Hamerstrand, Black & Glover 1981).

$$\text{TI (mg/g of sample)} = \frac{A_{std}\text{-}A_{std}}{0.019 \times \text{sample wt. (g)}} \times \frac{\text{dilution factor}}{1000 \times \text{sample size (ml)}}$$

3.9 Methodology

3.9.1 Standardization of recipe for preparation of pearl millet crackers

The standardization of recipe for preparation of crackers with pearl millet, sorghum and soybean in various proportions such as (50:35:15), (60:30:10) and (50:40:10) were used for T_1, T_2, and T_3 respectively and evaluated with reference pearl millet based crackers alone (100:0) control. The addition of grind sugar and cardamom was standardized as per the taste and flavor to maintain the mouth feel and acceptability.

Table 3.1: Standardization of recipe for preparation of pearl millet crackers

	Control	T_1	T_2	T_3
Pearl millet flour (g)	100	50	60	50
Sorghum flour (g)	0	35	30	40
Soyabean flour (g)	0	15	10	10

3.9.2 Process of preparation of crackers

Crackers were prepared in the bakery plant. The basic ingredients used for making control crackers were pearl millet flour, sugar, oil, Ammonium bicarbonate, milk and cardamom. Three different formulation used for crackers preparation. Pearl millet flour were substituted with sorghum flour and soyabean flour at levels of 60%, 30% and 10%. All the other ingredients were weighed separately. The weighed ingredients were mixed. Milk was added accurately to formdough. The dough was then kneaded and rolled to a uniform thickness. The crackers were cut out with cutter. Then the crackers were baked at 160°C for 15-20 minutes, cooled to ambient temperature and packed in high density polyethylene bags.

Preparation of crackers

Pearl millet flour (60%) + Sorghum flour (30%) + Soybean flour (10%) + Milk (35ml) + Sugar (40g)

↓

Mixing and compounding

↓

Kneading and dough preparation

↓

Rolling/cutting (3cm×3cm)

↓

Baking at 160˚C for 15 min.

↓

Cooling

↓

Packaging and storage

Flow sheet No.1: preparation of pearl millet crackers

3.10 Sensory evaluation of a prepared product

The sensory evaluation has been defined as a scientific method used to evoke, measure, analyzed and interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing. Pearl millet crackers was evaluated for sensory characteristics like color, flavor, taste, texture and overall acceptability by a panel of semi-trained judges, comprised of doctoral students and academic staff members of the College of Food Technology, V.N.M.K.V., Parbhani. Samples were scored based on a nine-point hedonic scale. 5 to 9 panel members judged the products. Judges were asked to rate the product on 9 points Hedonic scale with corresponding descriptive terms ranging from 9 to 1 as ‘‘like extremely” to ‘‘dislike extremely”.

3.11 Microbial analysis of prepared crackers

Microbial study of pearl millet crackers incorporated with sorghum and soybean flour was carried by determining total plate count (TPC) and yeast and mold count. Microbial quality of crackers was determined by adopting the method of (Sachitra *et al.*, 2017). The methods used for determination of TPC and yeast and mold are discussed below.

3.11.1 Total plate count (TPC)

The total plate count of pearl millet crackers incorporated with sorghum and soybean flour was determined by using simply a total plate count agar (nutrient agar) method. The pour plate technique was employed for isolating microorganisms from the sorghum and soybean flour incorporated pearl millet crackers samples. The dilutions were made up to 10^{-2} by using 1 g of sample and 0.1 ml of aliquot was used for the isolation. All process was carried out in a strictly sterile area with the help of laminar air flow. The petri plates were then incubated the temperature of at 37°C for 48 hrs and results expressed in cfu/ml. Total plate count (TPC) of incorporated pearl millet crackers was examined and the effect of storage on microbial quality (TPC) of incorporated pearl millet crackers was examined on 0, 30, 60 and 90 days.

3.11.2 Yeast and mold

The yeast and mold count of incorporated pearl millet crackers was determined by using potato dextrose agar (PDA), the streak plate and pour plate technique were used for the isolation. The media was sterilized and poured into plates. The dilutions of sample were made up to 10^{2}as like TPC and then 0.1 ml of aliquot was used for streaking. The petri plates were then incubated at the temperature of 37°C for 48-72 hr and results expressed in cfu/ml. The yeast and mold count of incorporated pearls millet crackers was examined and the effect of storage on microbial quality (yeast and mold) of noodles was examined on 0, 30, 60 and 90 days.

3.12 Evaluation of packaging study of pearl millet crackers

Packaging study was carried out for 1 to 3 month using different types of packaging material. The selected sample and control of prepared bakery product were packed tightly in 2 types of the packaging materials. Crackers packaging materials used was HDPE and aluminum polyethylene laminate pouches were stored at room temperature. The samples were analyzed for sensorial quality at every 30 days interval (Dar, 2012).

3.13 Evaluation of textural qualities of pearl millet crackers

Stable Micro System TA-XT2 plus Texture Analyzer was used for texture profile analysis (TPA) of pearl millet crackers incorporated with sorghum and soybean flour and method adopted by (Salim-ur Rehman *et al.,* 2012).

The textural properties recorded were hardness, springiness, cohesiveness and fracturability. Cutting probe was used for texture evaluation. Test conditions for TPA determination were – pre-test speed: 1 mms^{-1}; post-test speed: 10 mms^{-1}, test speed: 3 mms^{-1}, trigger force: 50 g and probe travel distance held as 5 mm. The texture was measured by changing the compression plunger until it barely reached the cracker surface in the sample core. The plunger was lowered at constant velocity until it compressed the sample to a specified degree (compression percentage). The test was conducted using the procedure provided by (Chung *et al.,* 2014)

3.14 Estimation of theoretical energy value of pearl millet crackers

The energy value is determined theoretically by using values of crude protein, crude fat and total carbohydrate content of the sample and considering that 1 g of protein yield 4Kcal energy, 1 g of fat yield 9Kcal energy and 1 g carbohydrates yield 4Kcal of energy (Gopalan *et. al.,* 2004). Total energy value in Kcal is calculated by adding the above three energy values which give energy value per 100 g of sample.

3.15 Assessment of techno-economic feasibility

The production cost of prepared crackers was calculated by considering the cost of raw material processing and packaging cost was calculated.

3.16 Statistical analysis

All processing equipment and analysis of samples were run in triplicate. Analysis of variance was calculated using standard ANOVA procedure. The data obtained for various treatments were recorded and statistically analyzed by a complete randomized design (CRD) to find out the level of significance as per the method proposed by (Panse and Sukhatme 1957). The analysis of variance revealed at significance at $P< 0.05$ level. The standard error (SE) and critical difference (CD) at a 5 % level were mentioned where required.

CHAPTER – IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation entitled, " **Studies on development of pearl millet crackers incorporated with sorghum and soybean flour**" was carried out in Department of Food Chemistry and Nutrition with the collaboration of Department of Food Processing Technology, Department of Food Engineering, Department of Food Microbiology and Safety College of Food Technology,V.N.M.K.V., parbhani during the academic year 2019-21.

The purpose of this research project is to prepare a convenient food product which is whole replacemnet of wheat flour and maida by pearl flour and high in nutrition and ready to eat form considering the customer demand. Cereal grains and legumes play significant role in supplying the nutrients, as well as providing over 70 percent of the daily energy requirements (Edwards *et al.*, 1971). To become value-added products, the value of pearl millet crackers must be increased through the addition of sorghum and soybean flour that make them highly nutritious and more attractive to the buyer. Increasing the added value of the pearl millet crackers requires the development of food products that considering the voice of the customer. The research aimed to design food products based on easy to prepare, low in cost and easily available to the customer and to improve its acceptability.

Sincere efforts were made to develop pearl millet crackers incorporated with sorghum and soybean flour. Proximate composition, sensory attributes, textural attributes microbial study and packaging study of developed crackers were carried out. Techno-economic feasibility of developed crackers was also evaluated. The results obtained during present study are presented and discussed with respect to experimental data obtained during course of study and relevant information available in scientific literature under following headings and sub headings:

4.1 Physical properties of pearl millet, sorghum and soybean

4.2 Chemical composition of pearl millet, sorghum and soybean

4.3 Mineral composition of pearl millet, sorghum and soybean

4.4 Effect of soaking on composition of soybean

4.1 Physical properties of pearl millet, sorghum and soybean

Physical properties play an important role in designing the machinery and equipment during the harvesting and food processing. 1000 kernel weight used for determine grain yield . the true density and bulk density ued for drying, designing of soils and storage bins, separation of undesirable materials, seed purity determination and grading (Mohsenin, 1986). Angle of repose is used for designing of processing equipment (Barbosa *et al.*, 2006).

Different physical properties such as thousand kernel weight, bulk density, true density, porosity and angle of repose of pearl millet, sorghum and soybean were evaluated and results obtained are presented in Table 4.1.

Table 4.1: Physical properties of peral millet, sorghum and soybean

Parameters	**Mean value**		
	Peral millet	**Sorghum**	**Soybean**
1000 kernel weight (g)	14.01	30.2	110.28
Bulk density (g/cm^3)	0.62	0.67	0.74
True density (g/cm^3)	1.29	1.36	1.46
Porosity (%)	37.6	61.6	47.02
Angle of repose (°)	28	32°30	40°48

*Each value is average of three determinations

Data from Table 4.1 showed that the average 1000 kernel weight of pearl millet was recorded 14.01 g, bulk density of millets was found to be 0.62 gm/cm^3, True density was 1.29 g/cm^3, porosity was calculated and recorded 37.6 % whereas pearl millet showed the angle of repose of 28°. Engineering properties of pearl millet grain were calculated and it was found that result of pearl millet grain result reported by Chhabra, 2017.

Data from Table 4.1 showed that the physical properties of sorghum were evaluated 1000 kernel weight, bulk density, true density and angle of repose was 30.2 g/cm^3, 0.67 g/cm^3, 1.36 g/cm^3, $32^0$30 respectively. The resistance to air flow of bulk grain is the function of porosity. The highest value of porosity was recorded in sorghum was 61.6%. The similar results were obtained by Butti *et al.*, 2017.

The data in Table 4.1 revealed that 1000 kernel weight of soybean seed was found highest 110.28 g. Due to size difference large deviation was recorded in 1000 kernel weight. The bulk density and true density of soybean were 0.74 g/cm^3 and 1.46 g/cm^3 respectively. The porosity of soybean was 47.02 %. The angle of repose of soybean was 40°48. The results of soybean were close agreement to the results obtained by (Tavakoli *et al*., 2009). The bulk density and angle of repose founded similar with result of Chigbo, 2016.

4.2 Chemical composition of pearl millet, sorghum and soybean

Chemical composition generally represents the nutritional quality of product. It is necessary to determine the proximate composition of pearl millet so as to judge its effect on final product after utilization as a novel ingredient. The chemical parameters like moisture content, protein, fat, carbohydrate, crude fiber and ash content of pearl millet, sorghum and soybean were estimated and obtained data was noted in the Table 4.2 as shown below.

Table 4.2: Chemical composition of pearl millet, sorghum and soybean

Composition	Mean value		
	Pearl millet	**Sorghum**	**Soybean**
Moisture (%)	9.59±0.25	9.9±0.31	7.8±0.2
Fat (%)	2.2±0.21	1.58±0.21	19.5±0.54
Carbohydrates (%)	71.9±0.50	73.01±0.41	27.88±0.75
Protein (%)	12.8±0.30	11.5±0.34	38.52±0.38
Ash (%)	1.53±0.12	1.51±0.11	2.90±0.22
Fiber	2.0±0.11	2.5±0.14	3.4±0.31

*Each value is average of three determinations

It is observed that the moisture content of pearl millet found to be 9.59%. The fat content of pearl millet was noted to be 2.2%. The carbohydrate content was calculated and recorded to be 71.9% in pearl millet. Protein content in pearl millet was noted to be 12.8%. Pearl millet has reported to have crude fiber and ash contain 2.0 and 1.53 % respectively. The result obtained is similar to the study of (Malik, 2015) and (Taylor *et al.*, 2010).

The proximate composition of the sorghum flour was analyzed. Table 4.2 data show that compare to pearl millet and soybean, sorghum contain more amount of carbohydrate. The moisture, total fat, carbohydrates, total protein, crude fiber and total ash of sorghum are 9.9%, 1.58%, 73.01%, 11.5%, 2.5 % and 1.51% respectively. The similar results were obtained by that (Patekar *et al.*, 2017), (Chavan *et al.*, 2009) and (Jambamma *et al.*, 2011).

It was observed from the data presented in Table 4.2 that the soybean flour contained 7.8 percent of moisture. Crude fat, carbohydrate, crude protein and crude fiber of soybean flour were observed 19.5%, 27.88%, 38.52% and 3.40% respectively. Compare to pearl millet and sorghum, soybean contain more amount of protein, carbohydrates and fiber. Ash content of full fat soybean flour contained about 2.9 percent. Ash content is an indication of the level of minerals present in food material this suggests that soybean can help in boosting the mineral content of prepared product. The obtained results for the proximate composition of full fat soybean flour were found similar to that of results of (Kokani & Ranganathan 2018), (Chinma & Gernah 2007).

The results for the ash and crude fat are comparable to the results obtained by the (Kuzniar *et al.,* 2016).

4.3 Mineral composition of pearl millet, sorghum and soybean

Mineral know as the micro components and inorganic elements needed by the body as structural component and regulators of body processes. The mineral like phosphorus, calcium, iron, magnesium of pearl millet, sorghum and soybean were estimated and results presented in the Table 4.3.

Table 4.3: Mineral composition of pearl millet, sorghum and soybean

	Mean value		
Minerals	**Peral millet**	**Sorghum**	**Soybean**
Phosphrous(mg/100g)	288	489	671.43
Calcium(mg/100g)	41	34.12	245.23
Iron(mg/100g)	8	4.42	12.60
Magnesium(mg/100)	131	160	150

*Each value is average of three determinations

The data regarding calcium, phosphorus, magnesium, iron of pearl millet depicted in table pearl millet contain calcium 41 mg/100g. Phosphorus content of pearl millet was 288 mg/100g. Magnesium content in pearl millet was observed 131 mg/100g. The concentration of iron content 8 mg/100g was found in the pearl millet. The results obtained are more or less similar to the study findings of (Gopalan *et al.,* 2004), (Nithya *et. al.,* 2006) and (Gull *et al.,* 2014)

The data regarding phosphorus, calcium, iron and magnesium of sorghum and soybean was depicted in table 4.3. The concentration of phosphorus and calcium is higher in soybean as compare to sorghum was recorded to be 671 mg/100g, 245.23 mg/100g and 489 mg/100g, 34.12 mg/100g respectively.

The concentration of iron and magnesium of sorghum was found to be 4.42 mg/100g and 160 mg/100g respectively. All mineral composition of sorghum grain are comparable values were obtained by (Desai, 2015; Kayode, 2006). The concentration of iron and magnesium of soybean was found to be 12.60 mg/100g and 150 mg/100g respectively. The similar results were obtained with (Rohini *et al.*, 2015) and (Gopalan *et al.*, 1989).

4.4 Effect of soaking treatment on composition of soybean

Soaking is important treatment for soybean to adjust the moisture content and make it suitable for making flour. Proximate composition of soaked soybean after soaking was determined and comparison of composition was analyzed and results were tabulated in Table 4.4.

Table 4.4: Effect of soaking treatment on proximate composition of soybean

Parameters	Unsoaked Soybean	Soaked Sorghum
Moisture (%)	7.8±0.2	8.9±0.21
Fat (%)	19.5±0.54	20.45±0.57
Carbohydrate (%)	27.88±0.75	25.38±0.68
Protein (%)	38.52±0.38	37.47±0.35
Ash (%)	2.90±0.22	2.90±0.22
Fiber (%)	3.4±0.31	4.09±0.41

*Each value is average of three determinations

The soybean was soaked for 12 hrs in ambient temperature of water and then dried at 80°C for 8 hr to obtain best results. During the soaking of soybean, the rate of water absorption was initially high followed by slower absorption after some period so that moisture content gets increased from 7.8% to 8.9% due to water absorb during soaking. The protein content of soaked soybean was decreases from 38.52 to 37.47% due to loss of soluble protein occurs during soaking, hence soaked soybean flours generally exhibiting lower protein content than raw ones. The carbohydrate content of soaked soybean get decreased from 27.88 to 25 due to decrease in the oligosaccharides content during 12–14 hrs soaking of the soybean seeds (Egounlety and Aworth, 2003). The ash content did not vary significantly with soaked and unsoaked soybean in 12 hrs soaking. such as 2.90%. The fiber content of soybean slightly increases after soaking from 3.4 to 4.09% the similar result reported by (Solange *et. al.*, 2017).

4.5 Effect of soaking treatment on anti-nutritional content of soybean

The anti-nutrients content available in raw soybean seed were slightly reduced during soaking treatment effected on increasing nutritional quality of final product. The anti-nutritional content of soybean was analyzed and pertained in Table 4.5.

Table 4.5: Effect of soaking treatment on anti-nutritional content of soybean

Treatment	Trypsin inhibitor	Tannin	Phytate
Unsoaked	51.5	16.2	13.6
Soaked	47.2	14	11.26

*Each value is average of three determinations

Table 4.5 show that trypsine inhibitor content of raw soybean that is unsoaked soybean was 51.5 mg/100g and soaked soybean was 47.2 mg/100g. The trypsin inhibitor difference occurs in soaked and unsoaked soybean due to 12 hrs soaking treatment (Khattab and Arntfield, 2009). The tannin content in unsoaked soybean was 16.2 mg/100g and it was reduced in soaked soybean 14 mg/100g. Phytate content of soaked soybean was less with compare to unsoaked or raw soybean that is 11.26 mg/100g and 13.6 mg/100g respectively. The reduction of phytate content occurs in soaked soybean may be leaching of tannin content during soaking (Ramakrishna *et al.,* 2006) and the water-soluble nature of phytate resulted in decrease in phytate content. The similar results were reported by (Sharma *et al.,* 2013) for reduction in trypsin inhibitor, tannin and phytate content of soybean due to soaking.

4.6 Standardized recipe for crackers

Process of preparation of crackers

Crackers were prepared in the bakery plant. The basic ingredients used for making control crackers were pearl millet flour, sugar, oil, ammonium bicarbonate, milk and cardamom.

The organoleptic assessment of crackers was undertaken by ten personnel of the semi-trained panel and the marks were determined by assessing appearance, color, taste, flavor, texture and overall acceptability that are compared against control sample and standardized recipe decided presented in table 4.6.

Three different formulations used for crackers preparation are reported in table 4.6. Pearl millet flour was substituted with Sorghum flour and soybean flour at levels of 60%, 30% and 10%. All the other ingredients were weighed separately. The weighed ingredients were mixed. Milk was added accurately to form dough. The dough was then kneaded and rolled to a uniform thickness. The crackers were cut out with cutter. Then the crackers were baked at 160˚C for 15-20 minutes, cooled to ambient temperature and packed in high density polyethylene bags.

Table 4.6: Preparation of pearl millet crackers

Ingredient	Control	T_1	T_2	T_3
Pearl millet flour (g)	100	50	60	50
Sorghum flour (g)	0	35	30	40
Soyabean flour (g)	0	15	10	10
Sugar (g)	40	40	40	40
Milk (ml)	35	35	35	35
Cardamom (g)	2	2	2	2
Ammonium bicarbonate (g)	2	2	2	2

Control = 100 % Pearl millet flour

$\mathbf{T_1}$ = 50% pearl millet + 35% sorghum + 15 % soybean flour

$\mathbf{T_2}$ = 60% pearl millet + 30% sorghum + 10% soybean flour

$\mathbf{T_3}$ = 50% pearl millet + 40 %sorghum + 10 % soybean flour

4.7 Physical paramaters of prepared crackers

The physical properties of crackers give its quality such as appearance and packaging parameters which improve consumer attraction. The different physical properties including weight, thickness, width, puffiness and spread factor of control and selected (T_2) sample were evaluated and the data was presented in the Table 4.7.

Control sample

T_1 sample

T_2 sample

T_4 sample

Plate 4.1: Prepared crackers sample

Table 4.7: Physical properties of pearl millet crackers

Parameters	Control	T_1	T_1	T_3
Weight (g)	3.5	3.01	3.02	3.0
Thickness (cm)	0.44	0.46	0.48	0.46
Width (cm)	3.5	4.0	4.0	4.1
Puffiness (%)	65	67.95	68.75	68.54
Spread factor (%)	71	73	74	73

* Each value is average of three determinations

It was observed that the weight of crackers decreased gradually from 3.5 to 3.02 g with decreasing proportion of pearl millet flour. Also, there was simultaneous increase in thickness from 0.44 to 0.48 cm in control and selected sample respectively, due to increasing fiber percent in selected product. Similarly, the width of selected sample is more compare to control sample such as 4.0 cm to 3.5 cm respectively.

Puffiness present and spread factor increase in selected sample (74%) as compare to control sample (71%), as control sample having 100% pearl millet flour have hydrophilic sites available for competing, for the limited free water in dough. Rapid partitioning of free water of these hydrophilic sites occurs during dough mixing and increases dough viscosity, thereby limiting the crackers spread. The results obtained are more or less similar to the study findings of (Vijapurkar *et al.*, 2015) and (kulthe *et al.*, 2017).

The data obtained from Table 4.7 revealed that weight of T_1 sample and T_3 sample was 3.01 g and 3.0 g respectively. The thickness, width, puffiness and spread factor of T_1 sample and T_3 sample was 0.46 cm, 4.0 cm, 67.95%, 73% and 0.46 cm, 4.1 cm, 4.1cm, 68.54%, 73% respectively.

4.8 Proximate composition prepared crackers

Nutritional composition of control and selected sample T_2 was carried out and parameters like moisture, protein, fat, carbohydrate, crude fiber and ash content were evaluated. The obtained data was presented in the Table 4.8 as below.

Table 4.8: Chemical composition of crackers

Parameters	Control	T_2
Moisture (%)	2.4±0.05	2.2±0.04
Protein (%)	12.7±0.21	14.47±0.25
Fat (%)	8.8±0.15	12.63±0.18
Carbohydrates (%)	72.52±0.44	66.5±0.31
Ash (%)	1.57±0.01	2.0±0.02
Crude fiber (%)	2.01±0.03	2.2±0.04

* Each value is average of three determinations

The data obtained from the Table 4.8 revealed that the pearl millet crackers come under the category of non-perishable food commodity as product were prepared using oven heating such as baking technology, moisture content in control and T_2 sample was 2.4 and 2.2% respectively. The moisture percent was nearly same in control and selected sample.

With compare to control sample, T_2 sample contains more protein and it was observed that protein content of control and T_2 sample was 12.7 and 14.47% respectively. Due to incorporation of sorghum flour and soaking treatment soybean flour. With compare to control T_2 sample contain more fat. Fat content of the control and T_2 sample was 8.8 and 12.63%. Fat content are increase in selected sample due to addition of soaked soybean flour and less amount of edible soya oil at time of dough preparation.

T_2 sample contains less carbohydrate 66.5% than the control sample 72.52% due to the millets were found to be good source of carbohydrate and in selected sample quantity of pearl millet flour was less compare to control sample.

Ash content of the control sample was found to be less than T_2 sample due to pearl millet having the good quantity of ash content and also selected product are prepared by incorporated with sorghum and soybean flour which have also more in ash percent hence T_2 sample contain more percent of ash compare to control sample. The ash percent was found 1.57 and 2.0% in control and T_2 sample.

The whole grain sorghum and pearl millet had high fiber content even in comparison with whole grain wheat and whole grain wheat crackers. Crude fiber content in the control and T_2 sample was 2.01 and 2.2% respectively. Selected sample found to be the good source of nutrients with compare to control. These results are correlated with the results report by (Udaybeer *et al.*, 2017). Control sample result similar to (Vaijapurkar *et al.*, 2015).

4.9 Mineral content of prepared crackers

It is important to analyze the retention of minerals in the final product. The present investigation evaluated the presence of minerals in organoleptically proved the best samples of crackers Table 4.9 shows the results of mineral content in the crackers.

Table 4.9: Mineral composition in crackers

Minerals	**Control**	**T_2**
Phosphrous (mg/100g)	284	351.24
Calcium (mg/100g)	39	58.75
Iron (mg/100g)	6.7	7.58
Magnesium (mg/100g)	126	141.6

* Each value is average of three determinations

The figures concerning phosphrus, calcium, iron and magnsium of the control and slected sample is given in Table 4.9. The concentration of control and selected sample minerals was recorded to be 284 mg/100g, 39 mg/100g, 6.7 mg/100g, 126 mg/100g and 351 mg/100g, 58 mg/100g, 7.58 mg/100g and 141 mg/100g respectively. The mineral composition of selected sample were increase due to incorporation of sorghum and soybean flour into peral millet flour.

4.10 Organoleptic evaluation of crackers

The three samples (T_1, T_2 and T_3) and control were made differently with different level of pearl millet, sorghum and soybean flour to achieve a highly acceptable product. The organoleptic evaluation of crackers carried out by a 10-semi trained panel member based on 9-point hedonic scale and the score were given by evaluating the sensory attributes for crackers such as color and appearance, flavor, texture, taste and overall acceptability which was compared with control sample and expressed table 4.10

Table 4.10: Organoleptic evaluation of crackers

Sample code	Color and appearance	Flavor	Texture	Taste	Overall acceptability
Control	8.0	7.0	6.8	8.0	8.0
T_1	8.2	7.8	6.7	8.2	7.0
T_2	8.3	7.9	6.9	8.3	**8.1**
T_3	8.2	7.8	6.8	8.2	8.0
SE±	0.033	0.063	0.022	0.233	0.055
CD@5%	0.0709	0.135	0.425	0.496	0.106

* Each value is average of three determinations

The results obtained from the sensory score revealed that there was highest Overall acceptability score (8.1) for the T_2 sample with compare to control. For the parameters like color, flavor and texture sample T_2 showed the highest score. While sample T_1 showed the lowest score for all the parameters with overall acceptability score (7.0).

It was found that 100% replacement of wheat flour by pearl millet flour with incorporation of (40%) sorghum and (10%) soybean flour was most acceptable by the trained sensory panel. Increasing the concentration of sorghum 40% or above that was found to be unacceptable by the consumers and also by adding more soybean flour i.e., above 10% are affected on the texture of product. It was found that replacement of 100% wheat flour by pearl millet was unacceptable by sensory panel because the appearance of the pearl millet crackers was affected i.e., darker in color and bitter in taste and also found cracks in texture of crackers. Rancidity and bitterness of pearl millet flour can be reduced by thermal treatment by using oven for baking of crackers. So, develop good flavor and taste to the product. Hence, in the present investigation pearl millet flour can be incorporated up to 60% was found most acceptable as a standardized recipe. So, the acceptable limit of the sorghum and soybean flour was found to be acceptable at 30% and 10%. Therefore, by considering the above parameters it was found that sample T_2 was

Figure 4.1: Organoleptic evaluation of crackers.

having the highest score and superior than other samples hence it was selected for the further studies.

4.11 Textural studies of crackers

Textural property is one of the major factors contributing to the eating quality of crackers showed in Table 4.11.

Table 4.11: Textural analysis of crackers

Sample	Hardness (N)	Fracturability (mm)	Cohesiveness	Springiness
Control	29.70	12.5	1.464	4.8
T_1	24.31	9.85	1.321	3.0
T_2	23.216	9.32	1.204	3.12
T_3	24.86	9.53	1.153	3.0

* Each value is average of three determinations

Control: 100% pearl millet flour

T_2: 60% pearl millet + 30% sorghum + 10% soybean flour

Hardness, which is the most important textural characteristics for crackers, was measured as the peak force to snap the crackers. Control sample have more hardness because pearl millet protein has compact effect on hardness of product. In selected sample by incorporation of full fat soybean flour decrease the hardness of product. Hardness of control and selected sample were 29.70 N and 23.21 N respectively. Hardness of T_1 sample and T_3 sample was 24.31 N and 24.86 N respectively. The results are comparable with the findings of (Chevallier *et al.,* 2000).

Distance at which the cracker breaks known as the fracturability. The fracturability of control crackers sample was 12.5 mm which decrease in T_2 sample is 9.32 mm. due to addition of sorghum and soybean flour in cracker and also decrease the level of pearl millet flour compare to control sample. The fracturability of T_1 sample and T_3 sample was 9.85 mm and 9.53 mm respectively. The results are comparable with the findings of (Jauharah *et al.,* 2014).

The cohesiveness was found to decrease from an initial value of 1.46 to 1.20 of control cracker. The decrease in cohesiveness was probably due to increase in of fat content. The Cohesiveness of T_1 sample and T_3 sample was 1.321 and 1.153

respectively. The results are comparable with the findings of (Singh *et al.,* 2008). Springiness indicates the ability of sample to recover its height that elapses before the end of first compression and start of other. Springiness was found to decrease in crackers from an initial value of 4.8 to 3.12. Decrease in springiness has been related to the loss of porous structure in crackers as incorporation. The springiness of T_1 sample and T_3 sample was 3.03 and 3.0 respectively. The results are comparable with the findings of (Glibowski *et al.,* 2011).

4.12 Microbial study of crackers

Control and selected sample of crackers were study for microbial quality with respect to different storage period and were investigated for yeast and mold and total plate count. The results obtained for microbial quality of control and selected crackers store at room temperature presented in table 4.12.

Table 4.12: Microbial analysis of crackers

Sample	Storage periods	Microbial quality (cfu/ml)	
	Days	Total plate ($cfu/g\times10^3$)	Yeast and mold ($cfu/g\times10^3$)
Control	**0**	ND	ND
	30	0.4×10^3	ND
	60	0.9×10^3	0.5×10^3
	90	1.1×10^3	0.9×10^3
T_2	**0**	ND	ND
	30	0.5×10^3	ND
	60	0.9×10^3	0.5×10^3
	90	1.2×10^3	1.1×10^3

* Each value is average of three determinations

ND = Not Detected

Control sample = 100% pearl millet flour

T_2 sample = 60% pearl millet + 30% sorghum + 10% soybean flour

Data from table 4.12 showed the microbial quality of control and selected sample of crackers during 90 days storage. The microbial counts were not detected on the day of preparation in control and selected sample were observed. Where, the yeast and mould

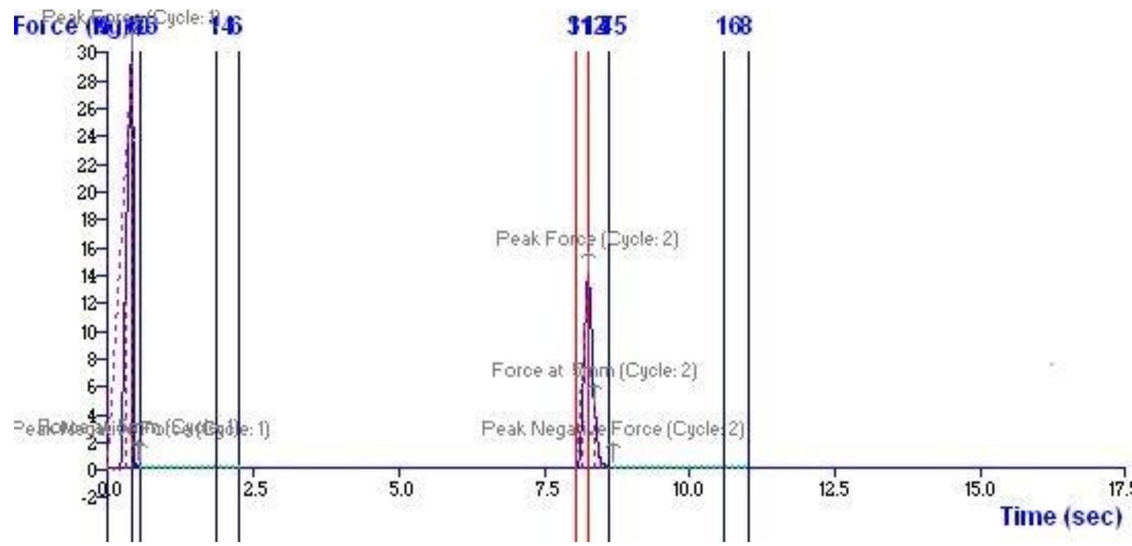


Figure 4.2: Representative graph of control sample Texture Profile Analysis (TPA).

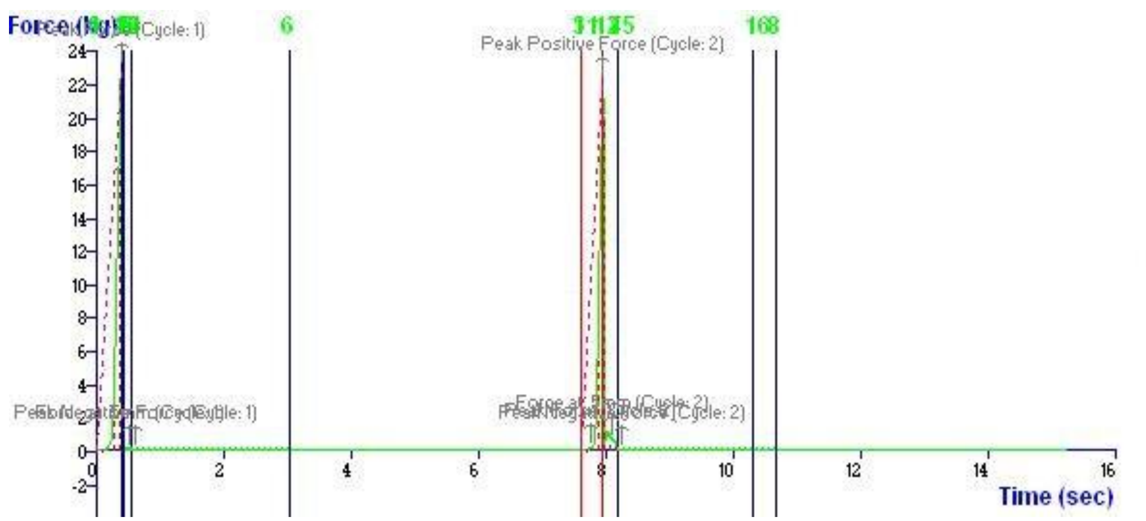


Figure 4.3: Representative graph of T_2 sample Texture Profile Analysis (TPA).

count of sample were not observed in control and selected during 30 days storage period. Due both samples contain less moisture content and it prepared by using heating methods such as use oven temperature for baking of crackers. It can be seen that the yeast and mould count of control and selected sample were increased from 60 to 90 days such as 0.5×10^3 cfu/g to 0.9×10^3 cfu/g and 0.5×10^3 cfu/g to 1.1×10^3 cfu/g respectively. Mould growth are slightly more in selected product compare to control sample because the nutrient composition was more in selected sample, microorganism need nitrogen, carbon dioxide and other gages for their growth.

Significant variations were observed in the total plate count for control over storage period. Total plate count observed in days of 30, 60 and 90 in control and selected sample were increased from 0.4×10^3 cfu/g, 0.9×10^3 cfu/g to 1.1×10^3 cfu/g and 0.5×10^3 cfu/g, 0.9×10^3 cfu/g to 1.2×10^3 cfu/g respectively.

The results of the microbial study of crackers showed that total plate count was detected during end of storage periods. The yeast and mold count in crackers sample were not detected during 30 days storage period. The yeast and mold count increases after 30 days as increasing storage periods. The packaging material High Density Poly Ethylene (HDPE) and ammonium foil polyethylene laminate pouches was seen to be best fitted for storage of crackers samples due to no detection of microbial and fungal growth throughout the storage period of crackers in HDPE. The growth of microorganism was not detected during the storage period of 30 days. Hence, it can be concluded that the crackers are foods which are having long shelf life with good microbial quality. The similar results were obtained by (Athawale *et al.,* 2015).

4.13 Packaging study on moisture content of crackers

Shelf-life determination is of great importance for the food industry to ensure that the consumer will obtain a high-quality product for a certain period of time after purchase. For the delivery of a product with maximum quality, the shelf-life of the packaged food product should be determined (Labuza and Hyman 1998).

Table 4.13 show that the packaging material such as high-density polyethylene pouches and aluminum foil polyethylene laminate pouches effect on the moisture content of control and selected sample. The moisture content parameters were analyzed at the interval of 30, 60 and 90 days.

Table 4.13: Packaging study on moisture content (%) of crackers

Sample	Storage periods	Packaging materials (Moisture %)	
	Days	HDPE	Laminate
Control	**0**	2.4±0.01	2.4±0.02
	30	2.8±0.02	2.7±0.03
	60	3.1±0.04	2.9±0.05
	90	3.5±0.05	3.3±0.02
T_2	**0**	2.2±0.03	2.2±0.04
	30	2.6±0.04	2.4±0.01
	60	3.0±0.06	2.8±0.03
	90	3.4±0.04	3.1±0.02

* Each value is average of three determinations

Control: 100% pearl millet flour

T_2: 60% pearl millet + 30% sorghum + 10% soybean flour

Table 4.13 show that the moisture percent of control and selected sample at the beginning was 2.4% and 2.2% which increased significantly to 3.5% and 3.4% in high density polyethylene pouches and in aluminum foil polyethylene laminate pouches to 3.3% and 3.1% respectively as the store in packaged material approximately three months. The increase in moisture content is due to nature of packaging materials and increases with increasing storage periods. (Rao *et al.*, 1995) reported that the interaction of packaging and storage time was found to be significant effect ($p \leq 0.05$) for the moisture content.

HDPE packed control and selected sample had 3.5 and 3.4% moisture, whereas laminate had 3.3 and 3.1% moisture. (Rao *et al.*, 1995) reported that crackers packed in metallised polyester or biaxial oriented polypropylene had higher moisture content than those packed in paper aluminium foil polyethylene laminate pouches. Hence, the crackers packed in laminate pouches absorbed lesser moisture during storage which might have been due to the impervious nature of aluminium foil in the laminate to air and water vapour. The similar result reported by (Dar, 2012)

4.14 Energy value of pearl millet crackers by incorporation of soybean and sorghum flour

Energy value is determined by using values of crude protein, crude fat, and total carbohydrate content of sample and considering that 1 g of protein yields 4 Kcal energy, 1g of fat yields 9 Kcal energy and 1 g of carbohydrate yields 4Kcal energy. Total energy value is calculated by adding above three energy value which gives energy value per 100g sample. The details of computing energy values of 100 g of each variation of crackers summarized in table 4.14.

Table 4.14: Therotical Energy value of crackers

	Nutrient per 100g			
Sample	**Protein**	**Fat**	**Carbohydrate**	**Energy value (Kcal/100g)**
Control	50.8	79.2	290.8	420.8
T_2	57.88	113.67	266	437.55

* Each value is average of three determinations

From table 4.14 it was found that total energy value of control crackers was 420.8 Kcal while total energy values of selected T_2 sample was calculated to be 437.55 Kcal. The increasing energy value is due to high concentration of proximate composition of prepared sample as incorporation of sorghum and soybean flour.

4.15 Techno-economic feasibility of crackers

The techno-economic feasibility of selected sample (T_2) was determined by calculating the total cost of production for 1 kg of product. The estimation cost of production was calculated by using standard calculation method. It was worked out on the basis of cost of raw material and processing cost (of 20 % of raw material cost) and finished product including packaging cost presented in table 4.15

Table 4.15: Techno-economic feasibility of 1 Kg crackers

Particular	Price for 1Kg (Rs.)	Quantity in (g)	Cost (Rs.)
Pearl millet	25/Kg	350g	8.75
Sorghum	30/kg	175g	5.25
Soybean	35/Kg	75g	2.62
Sugar	40/Kg	200g	8
Milk	60/lit	180ml	1.08
Ammonium bicarbonate	50/Kg	10g	0.5
Cardamom	2000/kg	10g	20
Total raw material cost (Rs.)			46.2
Processing cost (15% Raw material) Rs.			15
Packaging cost (5% Raw material) Rs.			4.76
Production cost of 1kg of crackers			65.96

No. of Crackers in 1 kg = 180 crackers

Cost of a cracker = Total cost / No. Crackers

Cost of a Crackers: Rs. 0.36 /- per crackers

The data given for the cost economy for prepared pearl millet crackers incorporated with sorghum and soybean flour were assessed for its cost of manufacturing. The results shown that to prepare 1 kg of pearl millet crackers incorporated with sorghum and soybean flour amount required was 65.96 Rs. including processing and packaging cost. The cost of prepare pearl millet crackers was low as compare to market sample.

CHAPTER – V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation attempts have been made for **"Development of pearl millet crackers Incorporated with sorghum and soybean flour".** The main objective behind this research work is to development of convenience food with utilization of cereals and legumes. The ingredients such as Pearl millet, sorghum and soybean were selected based on their properties. The selection of ingredients was done by evaluating its physical properties, Nutritional composition and mineral content. Product selection was done by organoleptic evaluation based on 9 point hedonic scale. Quality evaluation of final prepared product was carried out based on its physical parameter studies and evaluation of proximate constituents. Nutritional quality improvement was enhancing due to the incorporation of pearl millet and sorghum as carbohydrate source, soybean as protein source. These selected product i.e. cereals and legumes based crackers are more nutritious, having long shelf life, easy to prepared and economically more suitable.

- Physicochemical analysis of raw materials carried out and it was observed that the physically properties of pearl millet with respect to 1000 kernel weight, bulk density, true density, porosity and angle of repose was 14.01g, 0.62gm/cm^3, 1.29gm/cm^3, 37.6 % and 28^o respectively. The physical properties of sorghum varieties were evaluated 1000 kernel weight, bulk density, true density, porosity and angle of repose was 30.2 g, 0.67 g/cm^3, 1.36 g/cm^3 61.6% and 32˚30 respectively. Physical properties of soybean that is 1000 kernel weight of soybean seed were 110.28 g. The bulk density and true density of soybean were 0.74 g/cm^3 and 1.46 g/cm^3 respectively. The porosity of soybean was 47.02 percent. The angle of repose of soybean was 40°48^I
- Chemical study of pearl millet, sorghum and soybean revealed that the cereals that is pearl millet and sorghum both are good source of carbohydrate 71.9% and 73.01% respectively. The protein content of soybean was found to be high 38.52%. Soybean and sorghum are good source of phosphorus 671.43 mg/100g and 489 mg/100g respectively. Soybean content 3.40% fiber.

- Based on the organoleptic evaluation sample T_2 was selected with overall acceptability score 8.1. The ingredient composition for 100g of the selected sample contains pearl millet 60 g, sorghum 30g and soybean 10g. The selected sample was further evaluated for the physical, chemical, textural and microbial analysis. The study of physical properties of control and slected sample was found to be weight, width, thickness, puffiness and spread factor are 3.5g, 0.44cm, 3.5cm, 65%,71% and 3.02g, 4.0cm, 0.48cm, 68.75% and 74% respectively. The proximate study revealed that the prepared product was good in nutritional content with respect to the control sample. The moisture content of selected T_2 sample was 2.2%. Protein, fat, carbohydrate content of sample was found to be 14.47%, 12.63% and 66.5% respectively. The mineral composition in prepared crackers that is phosphorus, calcium, iron and magnesium are 351 mg/100g, 58.75 mg/100g,7.58 mg/100g and 141.6 mg/100g.
- The effect of sorghum and soybean flour on textural qualities of crackers showed that the incorporation of sorghum and soybean flour at the levels of 35:15, 30:10, 40:10 per cent in crackers formulation improved the different textural properties of the crackers such as hardness, springiness, cohesiveness and fracturability. These textural characteristics improved with increasing level of sorghum and soybean flour in crackers formulation. This clearly showed that with the addition of sorghum and soybean flour in crackers there was an improvement in the cracker's textural quality.
- Hardness, which is the most important textural characteristics for crackers, was measured as the peak force to snap the crackers. Due to addition of sorghum and soybean flour hardness of crackers decreases from 29.705 to 23.216. Distance at which the cracker breaks is known as the fracturability. The fracturability of control crackers sample was 12.5 mm which decrease in T_2 sample is 9.32 mm. due to addition of sorghum and soybean flour in cracker. The cohesiveness was found to decrease from an initial value of 1.46 to 1.20 of control cracker. The decrease in cohesiveness was probably due to increase in of fat content. Springiness indicates the ability of sample to recover its height that elapses before the end of first compression and start of other. Springiness was found to decrease

in crackers from an initial value of 4.8 to 3.12. Decrease in springiness has been related to the loss of porous structure in crackers.

- The microbial quality of control and selected sample of crackers during 90 days storage. The microbial count was not detected on the day of preparation in control and selected sample were observed. Where, the yeast and mould count of sample were not observed in control and selected during 30 days storage period. Due both sample contain less moisture content and it prepared by using heating methods such as use oven temperature for baking of crackers. It can be seen that the yeast and mould count of control and selected sample were increased from 60 to 90 days such as 0.5×10^3cfu/g to 0.9×10^3cfu/g and 0.5×10^3cfu/g to 1.1×10^3cfu/g respectively. Mould growth are slightly more in selected product compare to control sample because the nutrient composition was more in selected sample, microorganism need nitrogen, carbon dioxide and other gages for their growth. Total plate count observed in days of 30, 60 and 90 in control and selected sample were increased from 0.4×10^3cfu/g, 0.9×10^3cfu/g to 1.1×10^3cfu/g and 0.5×10^3cfu/g, 0.9×10^3cfu/g to 1.2×10^3cfu/g respectively.
- The results of the microbial study of crackers showed that total plate count was detected during end of storage periods. The yeast and mold count in crackers sample were not detected during 30 days storage period. The packaging material High Density Poly Ethylene (HDPE) and aluminium foil polyethylene laminate pouches was seen to be best fitted for storage of crackers samples due to no detection of microbial and fungal growth throughout the storage period of crackers in HDPE. The growth of microorganism was not detected during the storage period of 30 days. Hence, it can be concluded that the crackers are foods which are having long shelf life with good microbial quality.
- Packaging study on the moisture percent of control and selected sample at the beginning was 2.4% and 2.2% which increased significantly to 3.5% and 3.4% in high density polyethylene pouches and in aluminium foil polyethylene laminate pouches to 3.3% and 3.1 % respectively as the store in packaged material approximately three months. The increase in moisture content is due to nature of packaging materials. HDPE packed control and selected sample had 3.5 and 3.4%

moisture, whereas laminate had 3.3 and 3.1% moisture. Hence, the crackers packed in laminate pouches absorbed lesser moisture during storage which might have been due to the impervious nature of aluminium foil in the laminate to air and water vapour.

- The energy value of the control crackers sample per 100g of crackers was 420.8 Kcal. The energy values of the cracker's samples T_2 (60:40:10% pearl millet, sorghum, soybean flour) was 437.55 kcal. Hence the pearl millet crackers incorporated with sorghum and soybean flour provide good energy value to consumer.
- The prepared Crackers were studied for its economical feasibility and is compared to the sample available in local market. It was found that the cost of developed product was efficient than the market sample and nutritionally also developed product was superior against the product from market.

CONCLUSION

On the basis of findings, it was concluded that pearl millet crackers by incorporation of sorghum and soybean flour could be considered the best from both nutritional and sensory point of view. The pearl millet crackers at the ratio of 60:30:10 (Pearl millet:sorghum:soybean) was beneficial in terms of nutritional status which provides good amount of protein, fat and dietary fiber. Generally market crackers are made from wheat flour or maida which effect on consumer health problem. Whole replacement of wheat flour by pearl millet flour helped to enhance the carbohydrates and mineral availability and also increases the mouthfeel of the product. So, it gives the health benefits to gluten intolrant people. The product, pearl millet crackers provides 422.24 kcal/100g of energy value and delivered 14 percent of protein, 11 percent of fat, along with 69 percent of carbohydrate. The prepared pearl millet crackers product could be maintaining good enough quality attributes at ambient temperature for 90 days without any degradation in organoleptic and nutritional qualities. Therefore it was determined that low cost, easy to prepare, high carbohydrate, protein and crude fiber-containing crackers could develop an excellent alternative for ready eat breakfast meals for all age group people.

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APPENDIX

APPENDIX-I

VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH
COLLEGE OF FOOD TECHNOLOGY, VNMKV, PARBHANI

Organoleptic Evaluation of crackers

Date: / /2021

Name of Evaluator :---

Designation : ---

You are requested to evaluate the given samples and organoleptic qualities of the given samples. Express the acceptability of product by rating as per the given score point.

Sample Code	Sensory Attributes					
	Appearance	Colour	Taste	Flavour	Texture	Overall Acceptability
Control						
T1						
T2						
T3						
T4						
Remark:						

Hedonic Rating Scale

9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

Signature of the Evaluator

CURRICULUM VITAE

Name of candidate : Pandit Minal Gautam

Date of Birth : 19/11/1996

Nationality : Indian

Department : Food Chemistry and Nutrition

Permanent address : Khanapur nagar, Prbhani.

Mobile No : 8605661058

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Title of thesis : STUDIES ON DEVELOPMENT OF PEARL MILLET CRACKERS INCORPORATED WITH SORGHUM AND SOYBEAN FLOUR

Academic qualification

Course/ Degree	Name of college/Institute	University/ Board	Year of passing	Percentage (%)/ CGPA	Class/ Grade
SSC	Anand Madhemik Vidhayly, Parbhani	Maharashtra state board	2012	83.80	First
HSC	Sant Tukaram Higher Secondary Collage, Parbhani.	Maharashtra state board	2014	67.68	First
B. Tech (Food Technology)	College Of Food Technology, Parbhani.	Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani	2018	7.74	First class

Place: Parbhani
Date: 23/11/2021

Pandit
Signature of the candidate
Pandit Minal Gautam