EFFECT OF SPROUTING AND ROASTING ON SHELLING AND FUNCTIONAL CHARACTERISTICS OF WATERMELON SEEDS

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CERTIFICATE-I

This is to certify that the thesis entitled **"Effect of sprouting and roasting on shelling and functional characteristics of watermelon seeds"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Technology (Agricultural Engineering)** in **Processing and Food Engineering** to the Orissa University of Agriculture and Technology is a faithful record of *bonafid*e and original research work carried out by **Kumari Dipti Dhoba** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled **"Effect of sprouting and roasting on shelling and functional characteristics of watermelon seeds"** submitted in partial fulfillment of degree of **Master of Technology (Agricultural Engineering)** in **Processing and Food Engineering** of Orissa University of Agriculture and Technology, Bhubaneswar by **Kumari Dipti Dhoba** has been approved by the student's advisory committee after an oral examination on the same in collaboration with the external examiner.

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Bhubaneswar

Date: **Kumari Dipti Dhoba**

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percent
˚C	Degree centigrade
ANOVA	Analysis of Variance
cm	Centimeter
db	Dry basis
Dept.	Department
et al.	And other people
Fig.	Figure
g	Gram
h	Hour
min	Minute
mg	Milligram
mm	Millimeter
rpm	Revolution per minute
wt.	Weight
Kg	Kilo gram
Kg/h	Kilogram per hour
ml	Milliliter
OA	Overall Acceptability
hp	Horse power

Temp.	Temperature
Vs.	Versus
Avg.	Average
WAC	Water absorption capacity
FAC	Fat absorption capacity
ES	Emulsion stability
FC	Foam capacity
FS	Foam stability
WMS	Watermelon seed
WMSK	Watermelon seed kernel
WKR	Whole kernel recovery
No.	Number
AA	Ascorbic acid
NS	Normal sample
SS	Sprouted sample
RS_1	Roasted sample (0.5 min roasting period)
RS_2	Roasted sample (1 min roasting period)
RS_3	Roasted sample (1.5 min roasting period)
RS_4	Roasted sample (2 min roasting period)
OUAT	Orissa University of Agriculture and Technology

ABSTRACT

The seeds which are often the waste part of the fruits have not generally received much attention with a view to being used or recycled rather than discarded. Interestingly the seeds of watermelon (*Citrullus lanatus)* have higher protein, fat, vitamins, minerals and other essential nutrient activity. It is therefore necessary to evaluate the functional properties, the nutritional and anti-nutrients contents of these fruits and their waste materials so that the knowledge derived can be used to encourage adequate consumption of fruits and reutilization of the seeds in possible value added applications. The inability to effectively shell watermelon in order to meet the requisite capacity necessary for industrial utilization has been a hindrance to its use for large scale production of various commodities. A variety of health and nutritional benefits can be obtained from sprouting. Roasting can enhance flavor through caramelization and maillard browning on the surface of the food. Therefore, the present work aimed at studying the effect of operational speed (1500, 1750 and 2000rpm) and seed conditions (15, 20 and 25% mc) on shelling of soaked and sprouted watermelon seeds in a centrifugal shelling device through the performance indicators i.e. capacity, shelling efficiency, broken percentage and whole kernel recovery. The effect of sprouting and roasting on functional and anti-nutritional qualities of watermelon seed kernel (WMSK) was also evaluated. Blended malt powder was prepared from sprouted ragi and watermelon seeds at different proportion of ragi:WMSK as 70:30, 60:40, 50:50 and 0:100 to assess the acceptability.

The experiments have been conducted; data has been analyzed statistically using single factor and two-factor ANOVA and interpreted. Standardization of sprouting process indicated that a combination of 12h soaking in normal water followed by 48h sprouting period and 6h soaking in warm water (40ºC) followed by 48h sprouting period will result in more than 85% and 92% sprouting respectively. On sprouting, the fiber, ash and ascorbic acid was found to increase substantially from normal WMSK powder (8.01±0.36%, 5.95±0.40% and 29.52±0.94% respectively). On sprouting the WAC (135.37±0.60%), FAC (135.57±0.40%), ES (87.22±0.63%), FC (24.83±0.21%) and FS (18.77±0.40%) improved significantly. With increase in roasting time there was significant reduction in ascorbic acid as it is highly sensitive to heat. The roasted samples showed gradual decrease in WAC, FAC, FC and FS with increase in time of roasting and have significant difference from those of sprouted sample. On the contrary roasted sample was shown to have good emulsion stability. The unprocessed WMSK powder contained 311.99±0.80mg/100g oxalic acid and 411.27±1.54mg/100g phytic acid respectively. On sprouting the oxalic acid content and phytic acid content decreased significantly to 119.42±0.89mg/100g and 272.74±1.06mg/100g respectively. Dry heat treatment to roasted samples was not effective in reducing oxalic acid content and phytic acid content significantly. The shelling efficiency increased with a decrease in moisture content and increase in shelling speed. But the shelling efficiency of any combination was invariably higher in sprouted sample than soaked sample. On an average the percent broken was less in sprouted seed than soaked seed samples for any given set of process parameters. There was an increasing trend of breakage with increasing speed and decreasing moisture content. Maximum WKR of 66.53% was obtained at 20±1% moisture content at 2000 rpm for soaked sample where as WKR was maximum (69.13%) at moisture content of 20±1% and shelling speed of 1750 rpm for sprouted seed. Though the beverage prepared using only sprouted WMSK powder (S_4) scored highest overall acceptability (8.02), the ANOVA revealed that there was no significant difference between S_3 (ragi:WMSK, 50:50) and S_4 (ragi:WMSK, 0:100). Considering the nutritional profile, the sample S_3 (50:50) also has more balanced composition to be recommended for adult group of the society.

Chapter-1

INTRODUCTION

The watermelon (*Citrullus lanatus*) belongs to cucurbitaceae family. It is a tropical and subtropical fruit grows at a temperature of 25ºC. As a member of the cucurbitaceae, watermelon is related to the cantaloupe, squash and pumpkin and other plants that grows on vines on the ground. Watermelon is a good source of carotenoid and lycopene. Lycopene has been found to be protective against a growing list of cancer. Watermelon is delectable, thirst-quencher which helps quench the inflammable that contributes to conditions like asthma, atherosclerosis, diabetes, colon cancer and arthritis. Cucurbit seeds are source of food particularly protein and oil. De-hulled cucurbit seeds were reported to contain about 50% fat and 35% protein. Currently China is the largest producer of watermelon. The fruit has a thick rind (exocarp) with a fleshy center (mesocarp and endocarp) containing many smooth compressed seeds which are thickened at the margin. India grows 25 varieties and produces approximately 375,000 MT of fruits annually.

The watermelon seeds are rich in nutritional and medicinal values. These are rich in protein (28.33%), fat (47.37%), carbohydrate (15.31%), fiber (8.2%), ash (6.2%), calorie (557Kcal) and other minerals and can find application as a protein source in various food formulations and preparations (El-Adway and Taha, 2001).

The food property is characterized by the structure, quality, nutritional value and acceptability of a food product. A functional property of food is determined by physical, chemical, and organoleptic properties of a food. This provides the useful information to industry purpose and other alike on the subsequent incorporation of the different flours to produce natural, cheap and acceptable functional foods.

The aim of this research work is to determine the functional properties and nutritional and anti-nutritional qualities of the seeds with a view of harnessing it for consumption and possible industrial usage. The knowledge of the nutritive and the anti-nutrient content of various parts of these fruits will encourage their consumption in diverse ways and re-utilization of the vast amount of seeds discarded as waste for

human food, animal feed and fertilizer. Much has been reported on the nutritional value of watermelon seeds and how it can be used to effectively prevent nutritional deficiency in man as well as treat nutritional diseases. The seeds which are often the waste part of the fruits have not generally received much attention with a view to being used or recycled rather than discarded. Interestingly the seeds of watermelon have higher protein, fat, vitamins, minerals and other essential nutrient activity. The oil meal with high protein is used as feed and fertilizer, which could otherwise be used for food preparation after removal of anti-nutrients. Therefore it is necessary to evaluate the functional and anti-nutritional qualities of the seed and to prepare some value added products which encourage adequate consumption and effective utilization of the seeds.

Sprouting (malting) is a biochemical process which involves transition of a seed from dormant state to vital active state. Sprouting has been claimed to improve the nutritional quality of seeds and cereals by increasing the contents and availability of essential nutrients and lowering the levels of anti-nutrients. Long sprouting periods result in significant losses in dry matter through respiration, which is undesirable. Sprouting can increase protein content, mineral bioavailability and ascorbic content. Sprouted seeds can also be eaten either raw or cooked. Sprouting of seeds reduces the amount of starch they contain and boosts their nutritional value. Sprouting is cheap and more effective in improving nutritional value it can be incorporated in mixes to contribute the nutrition of people.

Roasting is known to be an important food processing method which includes cooking of food in an uncovered pan using dry heat where hot air envelops the food, cooking it evenly on all sides with high temperatures from any heat source without water to produce a well-browned exterior and a moister cooked interior. This processing treatment is also effective in eliminating the anti-nutritional factors in foods (Nzewi and Egbuonu, 2011). Roasting can enhance flavor through caramelization and Maillard browning on the surface of the food. It is also known to increase the antioxidant activity of the food product.

The processing of watermelon is imperative to further diversify its use. Shelling involves removing the outermost part (husk) from the watermelon kernel. Here, the seed is separated from the spiny husk. This operation can be carried out in the field or at the storage environment. Shelling of watermelon as a unit operation is

therefore an important step towards the processing of watermelon to its finished products. The farmers encounter several processing challenges of shelling, as it requires a relatively high expenditure of human energy which is a major concern. The inability to effectively shell watermelon in order to meet the requisite capacity necessary for industrial utilization has been a hindrance to its use for large scale production of various commodities. The conventional, traditional or manual method of shelling watermelon is inefficient, tedious and time consuming, thus limiting the availability of their products in the market. Thus the quest for a satisfactory, cheap and effective means such as mechanized shelling technique is of importance, for small and medium scale farmers. Different studies have been done on the design and development of shellers. But not much work has been done in the literatures on the design and construction of a mechanized centrifugal watermelon sheller. Therefore, the need for a more cost effective, simple, friendly, hygienic and technologically feasible system for shelling watermelon remains imperative. Hence, it is necessary to evaluate the performance of the constructed melon shelling machine (Sobowale *et al.*, 2015).

The fruit is seasonal and a huge amount of seeds get wasted every year due to lack of knowhow on process technology and not yet received much attention. Manual method of removal of cotyledon from the seed is tedious and time consuming. Traditionally, the seeds are removed from the rind and then allowed to dry outside in the sun, once dried the seeds are shelled manually and then milled into flour. Water melon seeds are among the under-utilized fruit by-products, though technology exists for decorticating the seeds, only a small proportion of the seed is commercially processed while the remaining is discarded (Lakshimi and Kaul, 2011).

Malnutrition is a very serious global health problem among the rural populace, especially the pregnant women and children in developing countries. There is a problem of protein malnutrition in the country is of great importance, as a large number of people in this part of the world do not have access to cheap protein sources. Food contains essential ingredients for sustenance of plants and animals. Production of seed is currently a waste product as it is often discarded after the fruit parts are consumed. Serious protein deficiencies and the high costs of pulses and animal protein sources have stimulated research on watermelon seed flours to create new use for food. For developing new sources of protein, these unexploited seed

flours as untraditional protein source may be used in food products. Watermelon seeds are packed with life-enhancing nutrients such as protein, iron, fibre, vitamin and other minerals. Watermelon seeds are major soup ingredients and they are used to thicken soups.

Keeping all these facts in view the present work aimed at the following objectives:

- To study the effect of sprouting and roasting on functional and anti-nutritional qualities of watermelon seeds.
- To study the effect of operational speed and seed conditions on shelling of watermelon seeds in a centrifugal shelling device.
- To prepare blended malt powder from sprouted ragi and watermelon seeds and to evaluate its quality.

Chapter-2

REVIEW OF LITERATURE

2.1 Introduction

Watermelon is a warm-season crop from the cucurbit family, which also contains other melons such as cantaloupe and gourds such as squash and pumpkin. There are three species of watermelon; Citrullus *lanatus*, Citrullus *ecirrhosus* Cogn., and Citrullus *colocynthis*. The domesticated varieties belong to the species C. *lanatus* which should not be confused with the wild populations designed as C. *lanatus* var. citroides (Robinson and Decker 1997). With over 1200 varieties available for a number of different growing conditions, watermelon is obtainable to be enjoyed throughout the world.

According to the USDA-ARS, in 1998 approximately 10% of watermelon production was sold as a minimally processed product (Perkins-Veazie *et al*., 2001). In 2003 the fresh cut fruit market increased 40% with watermelon being at least 14% of the total market. This signifies a rapidly increasing market for minimally processed watermelon and therefore an increased waste stream coming from processers.

2.1.1 Watermelon composition

Watermelon biomass can be categorized as three main components which are the fresh, seed, and rind. The flesh constitutes approximately 68% of the total weight, the rind approximately 30% and the seeds approximately 2% (Kumar, 1985). The sugar content of the watermelon varied greatly and is different in different parts of the fruit. The average sugar content of the center part is 8.86%, and has the highest sugar content compared to other parts of the fruit.

2.1.2 Health benefits of watermelon

Watermelon contains a number of health benefits. Watermelon act as a coolant, thirst, detoxifier, diuretic, febrifuge, and according to some natural healers it is an aphrodisiac. Pink-fleshed watermelon contains significantly higher levels of beta-carotene than yellow-flesh varieties.

We usually discard the tiny seeds scattered in it without realizing or rather knowing of their health benefits. These seeds are a rich source of nutrients and minerals and therefore, should not be discarded. The seeds are rich in vitamin B like thiamine, niacin, folate and minerals like magnesium, potassium, manganese, iron, zinc, phosphorus and copper. Besides, they are a great source of calories, with 100 grams of watermelon seeds providing around 600 grams of calories. Roasted watermelon seeds are served as a snack or used to garnish salads. In Nigeria they are used in certain soups. These seeds are excellent sources of multivitamin B which are vital for maintaining healthy blood, nervous system and effective immune response. These seeds can be used for treating diabetes.

2.1.3 Watermelon cultivation in India

Watermelon is generally grown in northwestern plains, as well as India's south and central regions. India grows approximately 25 commercial varieties. According to the National Institute of Industrial Research, watermelon is cultivated in Uttar Pradesh, Himachal Pradesh, Rajastan, Orissa, Gujarat, Punjab, Haryana, Assam, West Bengal, Karnataka, Orissa, Andhra Pradesh, Maharashtra, and Tamil Nadu. Watermelon comes in to season during the summer months, usually from April to June. Watermelon also appears during the off-season. However, these fruits are seldom the delicious, crisp and sweet types found in the summer months.

Watermelon cultivation in Odisha

Watermelon is commercially cultivated in many western districts of Odisha. Deogarh, Sonepur, Sambalpur are the major growing districts in Odisha. Soil and climatic condition of western Odisha is highly conductive for cultivation of watermelons. The agriculture department of the district through Agriculture Technology Management Agency (ATMA), a centrally sponsored program has helped the farmers with agricultural equipment. At some places farmers have been provided with water-pumps and medicine-sprayers at 50% subsidy for watermelon cultivation. The farmers have demand for government imitativeness to add value to the fruit by setting up cold storages for preservation and food-processing units to prepare juice, jams and other products made from watermelon and provision of insurance coverage for watermelon farmers.

2.2 Functional and anti-nutritional qualities of watermelon seed

El-Adawy and Taha (2001) studied the nutritional quality and functional properties of paprika seed flour and seed kernel flours of pumpkin and watermelon and the characteristics and structure of their seed oils. They found that all the three samples were rich in oil and protein, all flour samples contained considerable amounts of P, K, Mg, Mn, and Ca. Antinutritional compounds such as stachyose, raffinose, verbascose, trypsin inhibitor, phytic acid, and tannins were detected in all flours. Flour samples could be potentially added to food systems such as bakery products and ground meat formulations not only as a nutrient supplement but also as a functional agent in these formulations. Watermelon and pumpkin seed kernels and paprika seed could be utilized successfully as sources of edible oils and protein for human consumption. Seed kernel flours of watermelon and pumpkin as well as paprika seed flour have great potential for addition to food systems, not only as nutrient supplements but also as a functional agent.

Jyothi laxmi and Kaul (2011) proposed that watermelon (Citrullus vulgaris) seeds are high in protein and fat. They prepared defatted flour and protein isolate from watermelon seed meal and analyzed the chemical composition and functionality by standard techniques. They found that fat and protein together account for 3/4th the weight of watermelon seeds, this shows that it has good potential as a protein source and the functional properties of the WMS proteins were also good. They suggested that chemical composition of the seed flour has suitability as a matrix for mineral fortification and WMS is suitable for food formulations and concluded that the seed components exhibited good functionality with good macro and micronutrient density and can have application in many food products.

Oyeleke *et al.* (2012) gave a complete review on the functional properties as well the physicochemical properties of watermelon seed and seed-oil. They observed that oil and water absorption capacities for the seed were 123.5 ± 0.5 % and 116.3 ± 0.1%. The foaming capacity and stability (after 2 hr) were found to be 23.5± 0.1% and 62.5± 0.2% respectively while emulsion stability gave 0.325± 0.001%. They concluded that seed could be used in infant food formulation and the seed- oil could also be a useful source of oil for both domestic and industrial uses instead of depending solely on palm oil and peanut oil that are scarce and costly.

Johnson *et al.* (2012) evaluated the anti-nutrient contents of the pulp, seeds and rind of watermelon. They worked on both fresh and dried samples and found that the anti-nutritional components like saponin, alkaloid, hydrocyanic acid, phenols, oxalate, tannins, phytates were detected in all the samples but at a varying tolerable concentration. They concluded that the seeds, pulp and rind of the fruit contain a significantly high amount of saponin alkaloid and flavonoid in their pulp, seed and rind, the level at which the other phytochemicals occur is relatively small and found that there is a significant difference in the phytochemical content in the pulp, seed and rind of the fruit and Flavonoid was significantly high in the pulp and seed of watermelon. Alkaloid, Tannin, Phenol were significantly high in the rind of the fruit compared with the pulp and seed while Phytate and Oxalate were significantly high in the seeds compared with the pulp and rind of each fruit.

Mehra *et al.* (2015) worked on the dried seeds of musk melon (Cucumis melo) and water melon (Citrullus lanatus) and analyzed for different nutritional, phytochemical and antioxidant characteristics to understand its potential benefits. They observerd that the seeds are a good source of energy, carbohydrates, fat, proteins and minerals such as calcium, iron, magnesium, phosphorus and potassium and concluded that the seeds provide opportunities to develop as value added products, dietary supplements and medicines. The musk melon and water melon seeds are rich sources of valuable bioactive compounds and can be explored as nutraceuticals and also the oil of both were found to be rich in various unsaturated fatty acids which possess potential health benefits.

Omoboyowa *et al.* (2015) worked on the seeds of Citrulus lanatus and analyzed their phytochemical, proximate, nutrient and anti-nutrient compositions. They found that seeds contain substantial amount of saponnins, tannins, flavonoids, terpenoids and phenol. The concentration of alkaloids and steroids present in the C. lanatus seed were significantly ($p<0.0.05$) higher. There was generally low percentage proximate fractions of C. lanatus seeds in terms ash and fibre. This study has shown that C. lanatus seeds are good source of phytochemicals that are biologically important. The trace amounts of anti-nutrient compounds indicate that the seeds can serve as good dietary supplement. Also, these seeds contain appreciable level of proximate compounds, vitamins and minerals that are readily available. They could be consumed to supplement the scarce or non-available sources of nutrients.

Marie *et al.* (2015) reported the physico-chemical properties and mineral composition of four cultivar seed flours from Citrullus lanatus. They found the crude fat, crude protein, crude fiber, carbohydrate and starch contents from watermelon seeds, within the range of 41.48 to 56.08%, 21.78 to 30.42%, 2.56 to 17.14%, 10.45 to 26.30% and 7.29 to 20.71%, respectively. The levels of moisture, ash, total and reducing sugars in the cultivar seeds tested were found to be 3.60-5.53%, 2.60-3.99%, 2.23-3.28% and 0.95- 1.34%, respectively. They concluded that watermelon seed flours contain an appreciable value of copper (336.23-1772.97 mg/kg), potassium (264.72-368.51 mg/kg), magnesium (126.94-182.13 mg/kg) and calcium (45.31-60.77 mg/kg). The seed flours produced seems to be interesting for food and pharmaceutical industries.

2.2.1 Effect of processing conditions on functional and anti-nutritional qualities

Yagobu and Abdalla (2007) studied on comparative effects of domestic processing methods on chemical composition, in vitro digestibility of protein and starch in bambara groundnut (Voandzeia subterranea). They found that different methods showed varied deviation of nutrients and anti-nutrients from the raw seeds. Germination significantly increased protein content and decreased starch level. Thermal treatments, specially roasting, were more effective in reduction of total polyphenols. Germination was the best method to eliminate phytic acid and to increase in vitro protein digestibility. Cooking, in particular of the presoaked seeds, was most effective in improving in vitro starch digestibility. The foam volume from the flours indicates a significant decrease as a result of soaking, germination, cooking and roasting. Germination (4 and 6 days) significantly improved foam stability in water. The emulsification stability in water of almost all samples studied was significantly decreased.

Badifu (2010) studied on dry seeds of melon of different variety (Citrullus vulgaris, Citrullus lanatus, Colocynthis citrullus). He determined the germination, toasting and boiling on proximate composition, phytic acid, oxalate, total phenols, hydrocyanic acid and saponin contents were determined on control and treated samples. There was about 2-4% protein increase in kernels from 48 h germinated seed but subsequent germination reduced the protein content by 9 to 10% was oil was also reduced by 7 to 10%. Anti-nutritive and toxic contents of raw kernels were phenols 1.6 to 2.4 mg/100g, hydrocyanic acid 12.1 to 15.9 mg/100g and saponin 3.1 to 4.2%.

Toasting reduced 22 to 44% saponin and 24 to 54% total phenol contents of the kernels, germination reduced phytic acid, oxalate and phenols by 31 to 50, 26 to 41 and 17 to 67%, respectively, whereas boiling appreciably reduced all the components by about 40 to 81%, with phenols having the greatest reduction. The soluble anti nutritional and toxic components of the kernels were found in traces in the boiled water. The concentration of these components varied with species.

Mariod *et al.* (2012) studied the effects of roasting and boiling on compositional and oil stability of safflower seeds. They observed that the moisture, carbohydrate and fiber contents decreased because of roasting and boiling treatments while fat and protein contents increased. The effects of roasting and boiling with regard to loss and retention of the nutrients differed with only the roasting retaining more of the nutrients than boiling. Roasting at 180 ºC for 10 min seems to be the best technique for the quality of safflower seeds. They concluded that the proximate chemical analysis as well as seedcake amino acids and oil fatty acids of safflower seeds can be affected by roasting and boiling, therefore roasting and boiling techniques improve the nutritional value of safflower seeds by increasing the total and some individual amino acids.

Chandra and Samsher (2013) worked on the functional properties of different flours, that is, wheat flour, rice flour, green gram flour and potato flour. The functional properties (swelling capacity, water absorption capacity, oil absorption capacity, emulsion activity and stability, foam capacity and stability) and moisture content of flours were evaluated. Wheat flour had highest moisture content and emulsion activity while rice flour observed lowest value for foam capacity. Potato flour had highest value of swelling capacity, water absorption capacity, oil absorption capacity and emulsion stability. Green gram flour and potato flour have good functional properties which enhance the nutritional quality of the value added products which processed by addition of them.

Water melon (*Citrullus lanatus*) seeds were subjected to three different processing methods (sun drying, roasting and boiling/oven-drying).Chemical composition, functional properties and storage characteristics of sun-dried, roasted and boiled/oven-dried flours were investigated. The processed flours were stored for five weeks at room temperature (28 ± 1°C) and moisture content was determined

weekly. The result shows that roasting significantly reduced ($P < 0.05$) all the functional properties of the flour, there was a significant difference ($P < 0.05$) between sun dried samples in terms of water and fat absorption, viscosity and least gelatin concentration except for foam capacity. Roasting and boiling/oven-drying decreased the foam capacity; however boiling for 10 minutes then oven dry at 50°C for 12 hours proved to be more effective than sun drying and roasting in improving the functional properties of the water melon seed. The results of this study have shown that boiling/oven-drying was a better processing method compared to roasting and sun-drying in terms of proximate composition and functional properties. There was no adverse increase in moisture content, free fatty acid and peroxide value of flours stored for 5 weeks using the three processing methods. (Kiin-Kabari and Akusu, 2014).

Olanipekun *et al*. (2015) studied on the nutrient and anti-nutrient composition of raw and processed seed flours of the white variety of kidney bean (*Phaseolus vulgaris*) seeds. They milled the seeds into flour and analyzed and determined the proximate composition, some vitamins, minerals and anti-nutrients qualities. They found that processing significantly reduced carbohydrate content from 60.09% in raw to 54.49% in boiled sample. Protein was significantly increased from 20.92% in raw to 25.24% in roasted samples.Vitamins A and E were also significantly reduced by processing. Processing significantly reduced the anti-nutrient levels in the kidney bean. Roasting process reduced tannin by 52%. They concluded that kidney bean seed flours (raw and processed) had low fat and moisture content, indicating that it would keep well when stored. The processed and raw kidney bean seed flour is good sources of micronutrients and macronutrients They concluded that kidney bean flour as a blend in recipe development can help to alleviate the problem of malnutrition prevalent in rural areas.

2.3 Effect of operational speed and moisture content on shelling of seeds

Stephen and Lukman (2015) designed and evaluated the performance of a motorized melon shelling machine (using impact method). The average shelling efficiency was 94.78%, where as average broken and crushed melon seed was 5.2%.

Sobowale *et al.* (2015) designed a shelling machine for melon seeds and evaluated different parameters which include shelling efficiency; percentage of seed

shelled and damaged throughput and machine capacity. Shelling operation was carried using melon seeds of three different moisture contents (6.99, 11.90 and 18.32%) and at different shelling speeds of 2500 and 1500 rpm, while performance evaluation were evaluated. They found that shelling speed of 1500 rpm and moisture content of 18.32% has the best shelling efficiency of 76.30% and least percentage seed damage of 22.60%. Shelling speeds of the machine and seed moisture content of melon affects the rate, efficiency and percentage seed damage. The machine and throughput capacity of the equipment are 7.95 and 9.56 kg/h, respectively. They concluded that the shelling efficiency increases with an increase in moisture content and decrease in shelling speed, with an optimum moisture content and shelling speed of 18.32% and 1500 rpm respectively. The melon seed sheller is user friendly, does not require skilled labor and independent from any central electric power supply. The equipment design was found suitable for rural development.

Egbe Daniel *et al.* (2015) worked on performance evaluation and proposals for the creation and optimization of a melon-seed shelling machine and found that the initial performance was encouraging and an improvement shown over the current predominant method of manual shell removal. The performance evaluation followed by critical analysis on a locally constructed electrically powered melon seed shelling prototype (constructed by TAAKO Industries, Douala, Cameroon) was done. Results from the performance evaluation of the shelling unit revealed that for one shelling cycle, best efficiencies of 48% at 11.8Kgh-1 feed rate, 30mins wetting time, 450 feed angle and 22.5% at 12.23Kgh-1 feed rate, 30mins wetting time, 450 feed angle were obtained respectively for seeds type A and B. They found that that there is a general trend of improving performance with increase in this parameter and the feed rate and the soaking time had an effect on the outcome. For both seed types, a feed rate of 12 kg/hr was optimal with the highest shelling efficiency and lowest percentage of broken seeds. With respect to water soaking (termed the Critical Spreading Time).

Effect of moisture Content on shelling

Atiku *et al*. (2004) indicated that percent kernel damage was significantly affected with moisture content of both pod and kernel. Oluwole *et al*.(2007) evaluated the effect of moisture content on shelling ability of Bambara groundnut using a centrifugal cracker at three moisture levels (5.3, 9.6 and 12.2%, db) and found that the most effective performance was obtained at moisture content of 5.3% (d.b).

Singh Ranjit and Mangaraj Sukhdev found that a refined design of centrifugal Sheller for muskmelon seed decortications was developed and evaluated. The developed machine has a capacity of 5 kg/h which operates on 1400 r.p.m emery roll speed and seed moisture content of 25 % (wb), with this optimum condition, the shelling efficiency, seed damage and capacity was 51.0 %, 32 % and 5.0 kg/h, respectively.

Bamgboye and Adejumo (2004) studied that an expelling machine was developed for extracting oil from decorticated melon seeds. The expelling unit consists of an auger with decreasing pitches and the heating of seeds is achieved by generated steam which heats the surrounding of seeds passage. The machine was tested at auger speeds of 30, 40, 50 rpm respectively and three throughputs. Results showed that performance efficiencies increased with auger speed and throughout. Expelling efficiency of over 70% was obtained. The machine has expelling capacity of 24.4 liters/hr. of oil and throughput capacity of 502.64 kg/day.

Oluwole *et al.* (2007) conducted a study to determine the effect of moisture content on shelling efficiency of bambara groundnut using a centrifugal cracker. They subjected the samples to impact energy through a centrifugal impaction device operating at an angular velocity of 1920 r.p.m., using three different types of impellers. Data obtained on the percentage of fully shelled pods and unbroken seeds, fully shelled pods with broken seeds, partially shelled pods and unshelled pods were statistically analysed. They found that most effective performance was obtained at moisture content of 5.3% (d.b.), at which the shelling efficiency, percentage of damaged seeds, percentage of partially shelled pods and percentage of unshelled pods were 96, 3.4, 0.6 and 0, 86.6, 3.6, 5.6 and 4.2, 85, 2.4, 5.4, and 7.2% for the forward facing impeller, radially positioned impeller and the backward facing impeller, respectively.

2.3.1 Shelling of seeds in centrifugal sheller

While performing preliminary trials employing various de-hulling methods, it was observed that the de-hulling based on the principle of centrifugal action gave better performance for this seed as compared to de-hulling of melon seeds using rubber roll sheller and under runner-sheller. Melon seed having a flattened shape and loosely bound hull (Shukla, Srivastava & Gupta, 1992) presented an inherent difficulty in de-hulling of seed using rubber roll sheller and a considerable proportion

of the seed escaped un-decorticated and gave low de-hulling efficiency. On the other hand, in under runner-sheller, abrasion and attrition forces crushed the seed causing a high proportion of brokenness; the broken kernel thus have generated much more non-recoverable fraction of kernel.

Previously shelling of the seed to obtain the edible soft inner cotyledon is mostly done manually, because there are no commercially efficient and viable shelling machines to do the job. All the melon shellers that are being developed so far work majorly on the principle of seed rotation, impact application and cracking of shell. Olusegun and Adekunle (2008) developed the principle of seed rotation, cracking through twisting of the melon seeds. The seeds were passed through two wooden shelling discs, one fixed the other made to rotate in the clockwise, after which it changed rotation to the anticlockwise direction in one cycle. The shelling machine test which was carried out on varieties "E" and "N" melon seeds, achieved the maximum efficiency of 69.6% for variety "E" and 68.2% with variety "N", when the seeds were wetted with water. The eventual commercialization of this melon sheller will enhance health as more "melon" will be consumed.

Olatunde *et al.* (2015) worked on design, fabrication and testing of melon shelling machine. They considered nutritional and economical importance of the melon seed (Egusi) and less expensive means of processing the seed. They carried out the performance test and found that the machine has a power rating of 1.5hp and efficiency of 62.5% for shelled melon, 10% for unshelled melon, 10% for breakage and 17.5% for partially shelled melon.

Shukla *et al.* (1992) studied that the de-hulling based on the principle of centrifugal action give better performance for this seed as compared to de-hulling of melon seeds using rubber roll Sheller and under runner-Sheller. Melon seed having a flattened shape and loosely bound hull presented an inherent difficulty in de-hulling of seed using rubber roll sheller and a considerable proportion of the seed escaped un-decorticated and gave low de-hulling efficiency.

Gupta and Das (1998) studied that the performance of the centrifugal de-hulling system was found to be influenced by the moisture content of the seed or kernel (4-14% db), peripheral speed of the impeller (34-54 m/s) and feed rate (20-200 kg/h). The overall performance was expressed in terms of de-hulling efficiency,

percent of non-recoverable kernel fraction and specific energy consumption. De-hulling efficiency and non-recoverable kernel fraction increased with (i) increase in impeller speed (ii) decrease in feed rate, and (iii) decrease in the seed moisture content. The results of an optimization technique revealed that the best de-hulling performance could be obtained if the system is operated at peripheral speed of 40.7 to 44.5 m/s and feed rate of 100 kg/h using medium size seed with moisture content of 5.3 to 8.0% (db).

Simonyan *et al.* (2006) developed a motorized Bambara groundnut sheller. The sheller was evaluated to determine the effects of speeds of the shelling cylinder on the shelling efficiency, percent damage and the cleaning efficiency. Results showed that there was an increase in the shelling efficiency (SE) and percent damage (PD) with increasing speed. At low shelling cylinder speed of 0.93 m/s, the shelling efficiency was 81% and the percent damage was 4.7%. At shelling cylinder speed of 2.93 m/s, the shelling efficiency was 95% while the percent damage was 5.1%.

Swain *et al.* (2011) found that the development of a semi-automatic cashew nut Sheller suitable for the drum roasted cashew nuts incorporating a new shelling mechanism adopting the principle of impulse and tension This mechanism comprises of a set of seven numbers of chisel shaped pins and a set of five numbers of conical shaped pins through which the impulse and tensile forces were applied simultaneously to crack the nut and release the whole kernel intact. The performance of this Sheller was evaluated with three different sizes of nuts at 10.73% moisture content. The result on performance evaluation of the power operated Sheller indicated that the shelling capacity was found to vary from 14.44 nuts/min to 14.67 nuts/min with whole kernel recovery varying from 86.92% to 93.67% and the shelling efficiency varying from 86.17% to 88.61%.

Shittu and Ndrika (2012) designed, constructed and tested a power-driven melon seed shelling machine in order to solve the problems involved in melon shelling operation which is one of the major factors militating against the large scale production, processing and the use of this important oil crop. The shelling action was achieved by principle of a rotor that throws melon seeds against the shelling drum by centrifugal force and then the seeds were converged onto a spinning disc with vanes that provide impact force to remove the kernel from the shell. They found that the machine shelling efficiency increased with the increase in moisture content and speed.

Maximum shelling efficiency percentage of 95% was obtained at the seed moisture content of 26.6% d.b and at 2190 rpm shelling speed. Percentage seed damage was found to decrease with the increase in seed moisture content. Machine capacity and throughput capacity were 192 kg/h and 796 kg/h respectively. The analysis of variance showed that moisture content and machine shelling speed have significant effect on both shelling efficiency and percentage seed damage at 1% level.

2.4 Nutritional composition of blended powder

Jacob *et al.* (2005) studied the nutritional and anti-nutritional compositions of melon *(Citrullus lanatus)* seed flour. The results obtained from proximate analysis were: moisture content (7.10%), ash content (2.70%), crude protein (30.63%), crude lipid (49.05%), crude fiber(6.00%), carbohydrate (4.52%), dry matter (92.90%), organic matter (97.30%) and energy value (582.05Kcal/100g). The anti-nutritional factors analyzed were oxalate (26.40mg/100g), tannin (39.40mg/100g) and hydrocyanic acids (1.56mg/100g). They concluded that melon seed flour is a good source of important nutrients such as fat, protein, fiber and minerals.

Olalekan and Bosede (2010) gave a complete review on the chemical composition and functional properties of two underutilized legume seeds (Jack bean and Pigeon pea) flours and were compared with the popularly consumed Cowpea seed flour found in Igeria. The result revealed that Jack bean seed flour had the highest composition of ash (6.51±0.28%), protein (26.20±0.40%), carbohydrate (57.83±0.80%), foam capacity (20.67±0.41%) and emulsion capacity (71.73±0.44%). Pigeon pea had the highest composition of fat (4.78±0.22%), fibre (1.10±0.10%), energy (369.38±0.05kcal/100g), oil and water absorption capacity(148.17±%0.37; 189.77±0.28% respectively) and Cowpea had the highest value foam (15.70±0.31%) and emulsion (15.20±0.37%) stability. The result of this study support the consumption and industrial application of underutilized legumes (Jack bean and Pigeon pea) which compete favourable (or even better) in nutritional composition and some functional properties with Cowpea.

Otutu *et al.* (2015) worked on watermelon seeds and found that it has high protein content. They prepared flour from the seeds (whole seeds, shelled seeds and the shell and the flour) and evaluated the proximate composition, functional properties as well as mineral composition using standard methods. The crude protein of the

constituents ranged between 13.31 and 38.92% with the whole meal, having significantly ($p<0.05$) highest value. The fibre content of the shell (30.03%) was significantly highest. The shell had significantly ($p<0.05$) highest values of water absorption capacity (2.41 g/g) and oil absorption capacity (1.50 g/g) values. The whole meal recorded the highest value of the least gelation concentration (16.0%). The bulk and tapped density values were highest in the shell (0.54 and 0.71 g/cm3 respectively). The high values of the protein, fibre, minerals as well as functional properties could make the constituents good source of food supplements.

Rekha and Rose (2016) studied the proximate composition of dried watermelon seed by standard analytical techniques. They found that the mean nutritional content of the samples were: 68.4% protein, 6.4% moisture, 1.2% crude fibre, 47.1% Fat, Ash 2.6% Ash and 25.8% carbohydrate.

Chapter-3

MATERIALS AND METHODS

The careful observation of literature on watermelon seeds revealed that the research work conducted so far concentrated only on analysis of nutritional and antioxidant qualities of watermelon seed and seed oil. Effect of different processing operation on quality characteristics of the seed has not yet been studied. Therefore, process parameters are required to be optimized for removal of cotyledon from seed. The materials used and the methods followed for these studies have been described in this chapter.

3.1 Experimental design

In order to conduct the experiment in a systematic and efficient manner the entire experimental work was divided into various components. Before starting the experiment the independent variables and their levels were decided. The relevant parameters through which the inference of the experiment was to be predicted were selected as dependent parameters. Such plans were designed objective wise and are presented below.

3.1.1 Effect of sprouting and roasting on functional and anti-nutritional quality

Independent parameter:

1. Normal Seeds
2. Sprouted Seeds
3. Roasted Seeds (Temperature-100ºC, Time- 0.5min, 1min, 1.5min, 2min)

Fixed parameter: Seed Powder (60 Mesh sieve)

Drying 50±2ºC (Tray dryer)

Dependent parameter:

1. Moisture Content(%db)
2. Functional Quality
    - Water absorption capacity (%)

- Fat absorption capacity (%)
- Emulsion Stability (%)
- Foam Stability (%)
- Foam Capacity (%)
- Ascorbic acid (mg/100g)

3. Anti-nutritional Quality
    - Phytic acid (mg/100g)
    - Oxalic acid (mg/100g)

3.1.2 Effect of operational speed and seed conditions on shelling of watermelon seeds

Independent variable:

1. Shelling Speed (1500rpm, 1750rpm, 2000rpm)
2. Moisture Content (15%, 20%, 25% db)

Dependent variable:

1. Shelling Efficiency (%)
2. Percentage of broken seed (%)
3. Whole kernel recovery (%)
4. Capacity(kg/h)

3.1.3 Preparation and evaluation of blended malt powder

Independent variable:

1. Ragi:Watermelon(70:30, 60:40, 50:50, 0:100)

Fixed parameters: Sprouting: 2mm
Drying: 50±2ºC

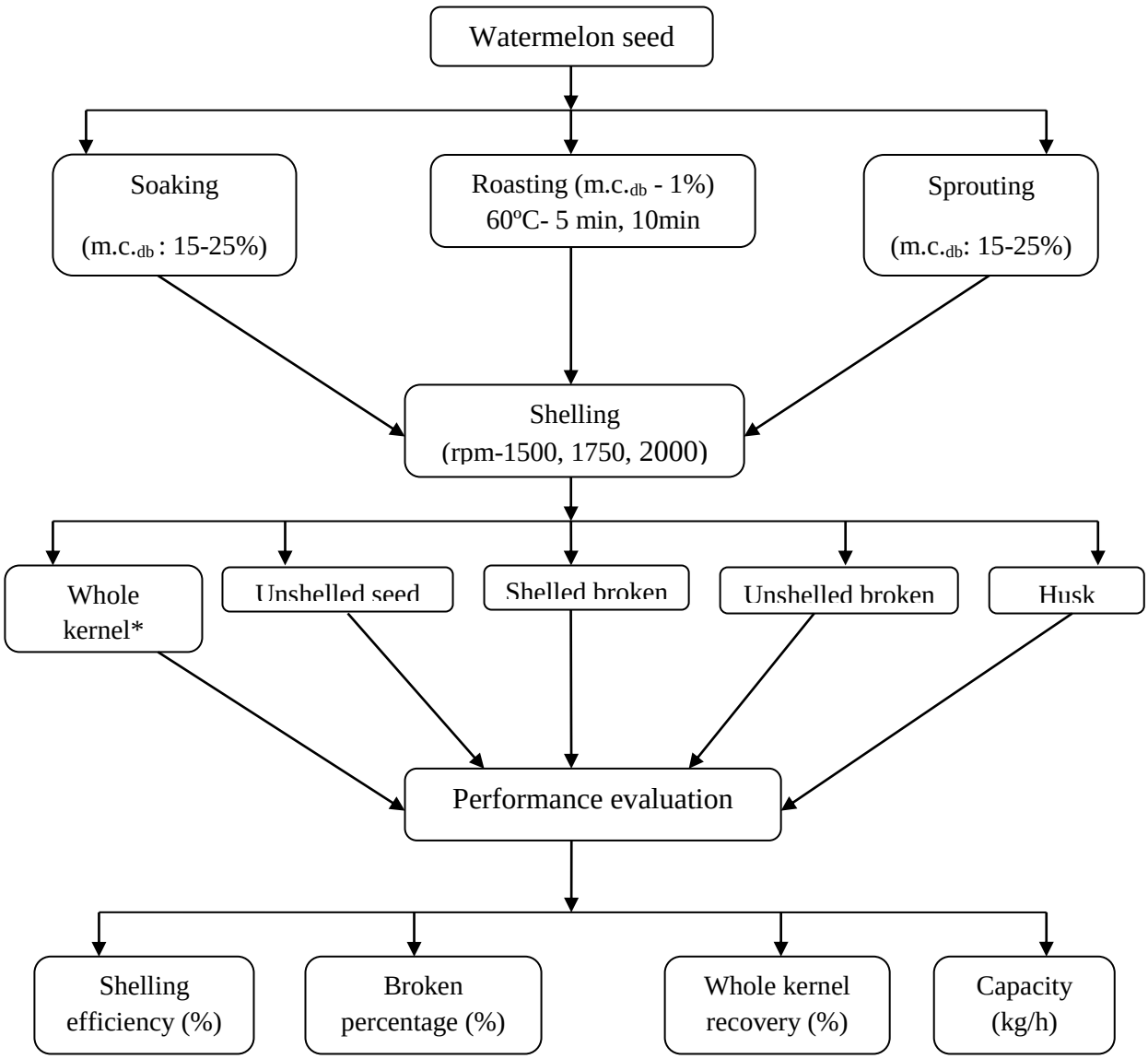
Dependent variable:

1. **Moisture content**
2. **Nutritional Quality**
    - Protein (%)
    - Fat (%)
    - Carbohydrate (%)
    - Ash (%)
    - Fiber (%)
3. **Sensory Evaluation**

- Colour
- Flavour
- Taste
- Consistency
- Overall Acceptability (By composite scoring)

3.2 Experimental plan layout

At the outset, the layout of the experimental plan has been prepared and presented in Figure 3.1.



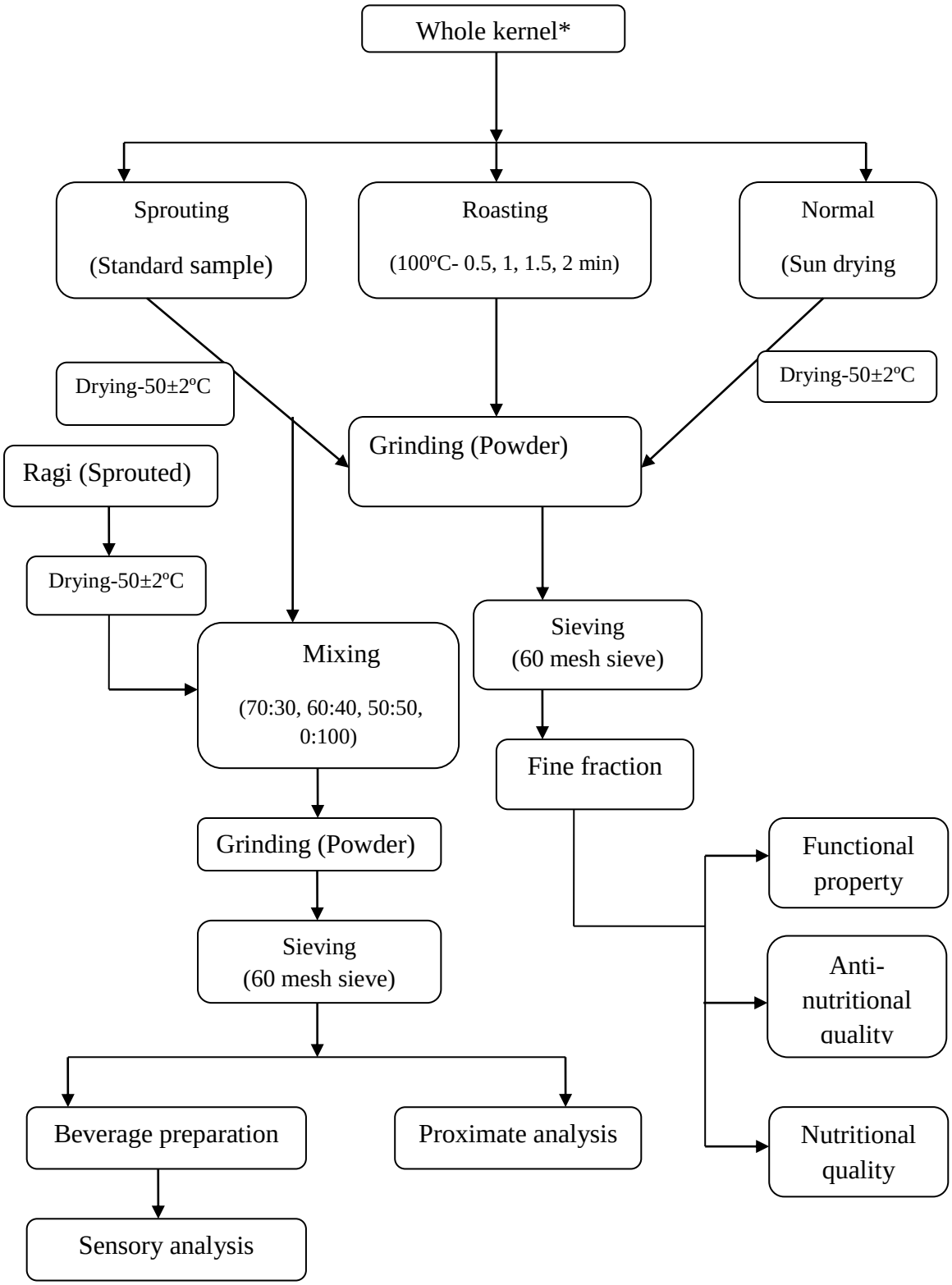


Figure 3.1 Layout of experimental plan

3.3 Experimental Procedure for sample preparation

3.3.1 Preparation of normal seed kernel powder

Matured watermelon fruits (fresh condition) were collected from the local market. The pulp was removed and the seeds were collected. The seeds were properly washed and sun-dried for 2-3 days. The collected seeds were sorted to remove damaged and immature ones and stored for further use. The seeds were shelled and the shelled seeds were dried at 50±2ºC in a tray drier till three consecutive readings were obtained. Then the seed kernels were grinded with a kitchen blender. The powder was packed and stored at room temperature in an airtight container to prevent any gain in moisture.

3.3.2 Preparation of roasted seed kernel powder

The de-hulled watermelon seeds were further used for making roasted seed kernel powder. The seed kernels were roasted by using induction cooker at 100ºC temperature for different time interval (0.5min, 1min, 1.5min and 2min). The roasted samples were grinded separately with a mixer grinder for 5 minutes in order to achieve uniformity in blend and the powder was packed in an airtight container to prevent any gain in moisture and stored at room temperature.

3.3.3 Standardization of sprouting process for watermelon seed kernel

In order to standardize the sprouting process of watermelon seed kernel to obtain maximum sprouting percentage, kernels were soaked for 4h, 6h and 12h (50 kernels for each treatment) in both normal and warm water. The soaked kernels were subjected to sprouting period of 12h, 24h, 36h and 48h respectively in a sprout maker. The number of kernels sprouted after designed interval of time was counted and the percentage of sprouting was calculated. A kernel was considered to be sprouted with a sprout length of 1 to 2 mm (Murugkar *et al*, 2013).

3.3.4 Preparation of sprouted seed kernel powder

. The stored watermelon seeds were shelled and kernels separated from the husk. The seed kernels were soaked in warm or normal water at 29°C for 4h, 6h and 12h respectively for optimum soaking and sprouting period. The sprouted kernels were dried in a tray drier at 55±2ºC till three consecutive readings were obtained. The dried kernels were powdered finely and stored.

3.4 Shelling of watermelon seed by centrifugal sheller

In centrifugal impact decorticator, seeds are fed into a rotating impeller assembly consisting of two discs that are separated by a number of radial vanes (Plate 3.1). By driving the impeller around at an appropriate speed, these vanes impart radial acceleration to the seeds. They are then discharged towards a peripheral target against which they impact and break open. The severity of the subsequent impact is determined by the impeller speed which must be high enough to fracture the shell, but not so high as to cause excessive damage to the kernel.

An experimental centrifugal decorticator has been fabricated in the department of APFE for shelling of watermelon seed (Plate 3.2). The main components of the centrifugal sheller consist of mainframe, hopper, impeller having 3 radial vanes and a drive unit. The impeller was mounted on a central shaft and was driven by a 0.5 hp single phase AC motor in conjunction with a variac for speed regulation. The impeller configured with forward curved radially pitched aluminium vanes was concentrically positioned within a stationary mild steel casing. The seed flying from the rotating impeller strike the metal casing. A hopper is attached to the de-hulling unit for feeding. The detailed specification is given in Table 3.1.

Table 3.1 Specification of the experimental centrifugal sheller

Sl. No.	Parameter	Size
1	Impeller disc diameter	40cm
2	Vane height	2.5cm
3	Clearance between casing and impeller	3.8cm
4	Casing diameter	47.6cm
5	Hopper diameter	10cm
6	Hopper inlet	2.54cm
7	V belt pulley	67B
8	Motor	0.5hp
9	Drive to Driven pulley diameter ratio	3:02

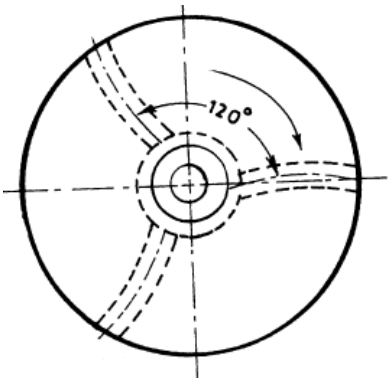


Plate No. 3.1 Impeller having three radial vanes

(a) Impeller disc

(b) Power transmission

(c) Hopper and casing

Plate No. 3.2 Developed experimental centrifugal Sheller

3.4.1 Conditioning of sample

The desired moisture content of watermelon seed ranging from 15 to 25% (db) for shelling experiment were obtained by conditioning the watermelon seeds as per the experimental design shown in section 3.1. The moisture content of the seed samples were to be maintained at 15%, 20%, 25% db respectively for shelling. In order to achieve those, dry seeds were soaked in water for 10h and sprouted for 48 hour to increase the moisture content to a higher level than 25%db. The surface moisture of soaked and sprouted seeds were wiped and then they were dried in a tray

dryer at 50±2ºC and the samples were withdrawn at intervals in order to achieve the desired moisture content. The desired moisture levels were obtained by drying samples up to the calculated weight. The samples were immediately sealed in polyethylene bags to prevent further moisture loss.

3.4.2 Testing of Sheller

For shelling test, the machine was allowed to run idle for about 10-15 min to attain a steady velocity. The speed of the impeller was adjusted to the desired value by a variac attached to the motor. About 50 g of pre-conditioned (soaked and sprouted) watermelon seed at the desired moisture level was fed to the centrifugal sheller. The sample with a particular moisture content was tested with different rpm (1500, 1750, 2000 rpm). After each experiment the seeds were carefully collected from the outlets. The whole kernel, unshelled seeds, broken seeds & kernels and husk were manually separated with care and weighed. For each experiment, shelling efficiency (%), capacity (Kg/h), whole kernel recovery (%) and broken percentage (%) were calculated using the following expressions.

Kernel to whole seed ratio was obtained by dividing the weight of kernel obtained from manual shelling of known amount of seed.

$$\text{Shelling efficiency (\%)} = \frac{(\text{Total weight of sample fed} - \text{Weight of unshelled sample} - \text{Weight of unshelled broken seed})}{\text{Total weight of sample fed}} \times 100$$

$$\text{Percentage of broken seed (\%)} = \frac{\text{Total weight of broken unshelled seed} + \text{Total weight of broken shelled seed})}{\text{Total weight of seeds fed}} \times 100$$

$$\text{Whole kernel recovery (\%)} = \frac{\text{Weight of whole kernel}}{\text{Weight of actual kernel percentage}} \times 100$$

$$\text{Capacity} \left(\frac{\text{Kg}}{\text{h}}\right) = \frac{\text{Weight of seed shelled (g)}}{\text{Time taken to complete the operation (min)}} \times \frac{60}{1000}$$

3.5 Formulation of blended malt powder

For the preparation of blended malt powder, ragi grain and water melon seed kernel were sprouted. Ragi was soaked for overnight (12hour) and kept in a sprout maker for 72 hours and where watermelon seed kernels were soaked in warm water for 6 hours and sprouted for 48 hours. The sprouted ragi and watermelon seed kernels were dried in a tray dryer at 55±2ºC for 3-4 hours. The dried grains were powdered finely and stored in air tight containers. Sprouted ragi powder and sprouted watermelon seed kernel powder are mixed at different proportion that is 70:30, 60:40, 50:50 and 0:100 (Ragi:Watermelon) respectively and packed in a airtight container for further use.

3.5.1 Estimation of blended malt composition

The composition of different proportion of blended malt has been determined using analytical methods. However in order to ease the calculation the proximate composition has been estimated theoretically (NIN, 2012) and was regressed to that of observed values to develop suitable mathematical equation.

3.6 Quality analysis

3.6.1 Functional properties of WMK powder

Water absorption capacity (WAC)

Water absorption capacity (WAC) of samples was determined according to the method of Lin *et al.* (1974). A 10% flour suspension (5g powdered sample was suspended in 50 ml distilled water) was stirred in a 50-ml centrifuge tube using a glass rod for 2 minutes at room temperature. After 30 minutes shaking the tube was centrifuged at 2100 rpm for 45 minutes. The freed water was carefully decanted in a graduated measuring cylinder and the volume recorded. The WAC expressed as ml of water retained per 1g flour. It is calculated from the following expression:

$$\text{WAC (\%)} = \frac{W_0 - W_1}{S} \times 100$$

Where, W_0=Volume of water taken (initial)

W_1=Measured volume of decanted water (ml)

S=Wt. of sample taken (ml)

Fat absorption capacity (FAC)

Fat absorption capacity (FAC) of samples was determined according to the method of Lin *et al.* (1974). A 10% flour suspension (5g powdered sample was suspended in 50 ml refined oil) was stirred in a 50-ml centrifuge tube using a glass rod for 2 minutes at room temperature. After 30 minutes shaking the tube was centrifuged at 2100 rpm for 45 minutes. The freed oil was carefully decanted in a graduated measuring cylinder and the volume recorded. The FAC expressed as ml of oil retained per 1g flour. It is calculated from the following expression:

$$\text{FAC (\%)} = \frac{W_0 - W_1}{S} \times 100$$

Where, W_0=Volume of oil taken (initial)

W_1=Measured volume of decanted oil (ml)

S=Wt. of sample taken (g)

Foam Capacity (FC)

Foam capacity of the sample was determined following the method described by Venktesh and Prakash (1986). A 3% flour suspension (3g powdered sample was suspended in 100ml distilled water) was stirred in a kitchen blender for 6 minutes and transferred to a 500 ml measuring cylinder and the volume of foam at 30 seconds was calculated and the increase in volume was expressed as a percent foam capacity.

$$\text{Foam capacity (\%)} = \frac{\text{Volume of foam AW} - \text{Volume of foam BW}}{\text{Volume of foam BW}}$$

Where, AW=after whipping, BW=before whipping

Foam Stability (FS)

Foam stability of the sample was determined following the method described by Venktesh and Prakash (1986). A 3% flour suspension (3g powdered sample was suspended in 100ml distilled water) was stirred in a kitchen blender for 6 minutes and transferred to a 500 ml measuring cylinder and left undisturbed for 30 minutes. The foam stability was determined by measuring the decrease in volume of foam as a function of time up to a period of 30 minutes.

Emulsion Stability (ES)

Emulsion stability (ES) of samples was determined according to the method of Mirhosseini *et al.* (2008). For emulsion stability test a 10% flour suspension (5gm powdered sample was suspended in 50ml distilled water) was stirred and transferred in to a 20ml test tube and stored for 2 weeks (15days) at room temperature (25$\pm$1ºC). Emulsion stability index (ESI) is calculated from the following expression:

$$\text{ESI (\%)} = \frac{\text{HE}-(\text{HC}+\text{HS})}{\text{HE}} \times 100$$

Where, ESI=Emulsion Stability Index (%)

HE=Initial emulsion height (cm)

HC=Height of cream layer (cm)

HS=Height of sedimentation phase (cm)

Ascorbic acid (AA)

Ascorbic acid or vitamin C content of watermelon seed powder was estimated by volumetric method. 5 grams of sample was grinded in a mortar and pestle by adding 10ml of 3% meta-phosphoric acid (HPO_3). It was then transferred to a beaker and 40ml of meta-phosphoric acid was added to it. Then it was centrifuged for around 10-15 minutes and the aliquot or the filtrate was collected. 5ml of standard ascorbic acid solution and 5ml of 3% meta-phosphoric acid was taken in a conical flask and mixed together and was titrated against the 2,6-dichlorophenol indophenols dye (Prepared dye solution) to get the dye factor. The appearance and persistence of pink colour was taken as end point. The amount of dye consumed (V_1 ml) is equivalent to the amount of ascorbic acid. Then, 2-10 ml of the aliquot or filtrate sample was taken and titrated with the dye to a pink end point which persists for at least 15 seconds. The aliquot of the sample taken should be such that the titration value should not exceed 3 to 5 ml. Ascorbic acid was calculated using following expression:

$$\text{Ascorbic acid } \left(\frac{\text{mg}}{100\text{g}} \text{metaphosphoric acid}\right) = \frac{\text{titre} \times \text{dye factor} \times \text{volume mad up}}{\text{extracted liquid taken for estimation} \times \text{wt. of sample taken for extraction}} \times 100$$

Where, Dye factor = 0.5/titre

3.6.2 Anti-nutritional qualities of WMK powder

Phytic acid determination

The phytate content of each of the samples was determined through phytic acid determination using the procedure described by Lucas and Markaka (1975). 2 g of each sample was taken in to 250 ml conical flask and soaked in 100 ml of 2% concentrated hydrochloric acid (HCl) for 3 hour. After 3 hour the soaked sample was filtered through a double layer filter paper. 50 ml of each of the sample filtrate were placed in a 250 ml beaker and 107 ml of distilled water was added to improve proper acidity. 10 ml of 0.3% ammonium thiocyanate solution was added to each sample solution as indicator and titrated with standard iron chloride solution which contained 0.00195 g iron/ml and the end point was signified by brownish-yellow colour that persisted for 5 min. The percentage of phytic acid was calculated using following expression:

$$\text{Phytic acid content } \left(\frac{\text{mg}}{100\text{g}}\right) = \frac{\text{T} \times 0.00195 \times 1.19 \times \text{W}}{2} \times 100$$

Where, T= Titration value

W=Weight of sample (g)

Oxalic acid determination

The oxalate content of the samples was determined using titration method. 2 g of each sample was placed in a 250 ml volumetric flask suspended in 190 ml distilled water. 5ml concentrated hydrochloric acid (HCl) solution was added to each of the samples and the suspension digested at 100ºC for1h. The samples were then cooled and filtered. The volume was made up to 250 ml mark of the flask by repeated washing by distilled water. 50ml of aliquot was taken from the prepared sample and 3-4 drops of methyl red indicator was added, followed by the addition of concentrated ammonium hydroxide(NH_4OH) solution (drop wise) until the solution changed from pink to yellow colour. Each sample was then heated to 90ºC in a water bath and 10 ml of 5% calcium chloride ($CaCl_2$) solution was added with stirring consistently. After cooling, the samples were left overnight. The supernatant were decanted and the precipitates completely dissolved in 10 ml 20% sulphuric acid (H_2SO_4). Then the sample was heated until near boiling and then titrated against 0.05 M standardized potassium permanganate ($KMnO_4$) solution to a pink colour end point which persisted

for 30 sec. The oxalate contents of each sample were calculated using the following expression:

$$\text{Oxalic acid content } (\frac{\text{mg}}{100\text{g}}) = \frac{\text{T} \times 2.2}{\text{W}} \times 100$$

Where, T=Titration value

W=Wt. of sample (g)

3.6.3 Proximate composition determination

The proximate composition (Fat, Crude protein, Crude fiber, Ash and Moisture content) were determined using the methods of A.O.A.C [1995]. Carbohydrate content was estimated by the difference in value obtained when all the proximate composition values were subtracted from 100%.

Moisture content (MC)

Moisture content of the powdered sample was measured by gravimetric method using hot air oven. At first the weight of the empty can was measured using the Mettler Toledo digital balance [(Switzerland) of model number ME54E]. Then the sample along with can was measured and kept in Uni-tech hot air oven (Model-UTS 1.01c) at 105°C for 24 hours without closing the can. The can was then taken out from oven and was allowed to cool in a desiccator. After attaining the temperature at room temperature the weight of the can along with sample was measured.

Crude protein (CP)

Kjeldahl method is used for determination of crude protein content in watermelon seed kernel. This includes digestion followed by distillation and followed by titration

During the digestion step all the amino nitrogen is converted to ammonium radical. Distillation involves the separation of the nitrogen from the digestion tube. This is done by raising the pH with NaOH and by doing this the ammonium radical is converted to ammonia. On heating, the ammonia is distilled out and collected in 4% boric acid as a trapping medium. In the titration method the determination of the amount of nitrogen in the condensate flask is done by titrating with a standard solution of 0.1N H_2SO_4 in the presence of mixed indicator.

0.3-0.4g of feed sample was digested on heater after adding 5 ml commercial grade sulphuric acid and 2.5 g digestion mixture (copper sulfate: sodium sulfate in 1: 5 ratio) until it became clear. The flask was allowed to cool and about 50 ml of water poured slowly along the neck of the flask. The content was shaken and transferred completely into 250 ml volumetric flask by giving repeated washings with tap water and the final volume was made up to 250 ml. 10 ml aliquot of digested feed samples were distilled in a Micro Kjeldahl assembly by adding 10 ml of 40% sodium hydroxide solution. Gaseous ammonia thus released was trapped in 10 ml boric acid containing Tashiro's indicator (boric acid 20 g, 1% solution of methyl red, 12 ml; 1% solution of bromocresol green, 6ml; dehydrated alcohol, 200ml and distilled water 782 ml). The nitrogen trapped in boric acid was estimated by titrating it against 0.1N sulphuric acid. The normality of acid was checked by titrating against sodium carbonate using methyl orange as indicator. The value of blank was subtracted from sample readings. The crude protein content of samples was determined by the formula:

$$\text{Crude Protein } (\%) = \frac{14.01\times \text{(ml titrant-ml blank)} \times N \times 6.25}{W\times 1000} \times 100$$

Where, N = Normality (0.025)

W = weight of oven dried sample taken for digestion (g)

6.25 = Factor for converting nitrogen into crude protein of sample

Crude Fiber (CF)

The moisture free and fat extracted samples of feeds were refluxed with 200 ml of 1.25% Sulphuric acid for 30 minutes and washed with hot water to make the sample acid free. This was followed by refluxing with 200 ml of 1.25% Sodium hydroxide for 30 minutes and again washed repeatedly with hot water to make the sample alkali free. The sample left on refluxing was strained in a muslin cloth. The residue left after washing was dried at 100 ºC and weighed. After drying the residues were ashed in muffle furnace at 600 ºC for 3 hours. The loss in weight due to ignition was recorded as crude fiber.

$$\text{Crude Fiber } (\%) = \frac{W1 - W2}{W0} \times 100$$

Where, W_0=weight of dried material taken (g)

W_1=weight of crucible and content before ashing (g)

W_2=weight of crucible before ash (g)

Fat (Ether Extract)

A weighed quantity (about 2-3 g) of ground sample was taken in a thimble, plugged with cotton and extracted for 8-10 hours with petroleum ether (boiling point: 60-80°C) in Socs plus apparatus. The extracted oil in the oil flask was dried to constant weight at 100 ± 1°C. The ether extract was estimated as the difference in the weight of oil flask after and before extraction and was expressed as percent on DM basis as follows:

$$\text{Ether Extract (\%)} = \frac{\text{Weight of the ether extract}}{\text{Weight of sample on DM basis}} \times 100$$

Total ash (TA)

Approximately 3-4 g of feed sample (exactly weighed) was taken in a pre-weighed silica crucible and charred on heater to make smoke free. The crucible along with the sample was ignited at 550±5°C for 3h in muffle furnace. The furnace was allowed to cool down and the crucibles containing ash was taken out and kept in desiccator to cool down and then weighed. The difference in the weights of empty silica crucible and with ash gave the amount of total ash. The TA on DM basis was calculated from the following formula:

$$\text{Total Ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample on DM basis}} \times 100$$

3.6.4 Sensory evaluation

Sensory evaluation offers the opportunity to obtain a complete analysis of the various properties of food as perceived by human sense. Sensory evaluation is an important and the best method for evaluating the level of acceptance of any new food products developed. This also provides a light on quality and production control measures. The sensory evaluation was done using a nine point hedonic scale following the procedure of ISI (1997). The 9-point hedonic scale used the descriptive scoring i.e. like extremely 9, like very much 8, like moderately 7, like slightly 6, neither like nor dislike 5, dislike slightly 4, dislike moderately 3, dislike very much 2 and dislike extremely as 1. The attributes for the products under study considered were colour, flavor, taste and consistency. However, the overall acceptability was estimated using composite scoring. A panel of 20 semi trained members evaluated the

blended malt beverage prepared with different proportion of ragi and watermelon kernel malt powder.

Composite scoring test: The investigating attributes were given some weightage based on the judge's opinion regarding the importance given to a particular investigating attribute. The weight factors given to a particular subjective attribute was in such a way that the sum of the weigh factor for all the investigating attribute was 1. In composite scoring the scores allotted to each investigating attribute was multiplied by corresponding weight factor and then the average of all cumulative summation was considered to be the score of overall acceptability.

Statistical analysis

The results of the standardization of sprouting, proximate analysis, functional property and anti-nutritional qualities are given as means of triplicate samples. Statistical analysis of variance (ANOVA) was done to determine the significance differences among means which includes one way and two-way (with and without replication) ANOVA (F-ratio) and student' test. The statistically significant difference was defined as $p < 0.05$ and was regarded as significant in comparison with appropriate control. All data were expressed as MEAN± SEM.

(a) Watermelon seed kernel

(b) Sprouting in sprout maker

(c) Sprouted watermelon seed kernel

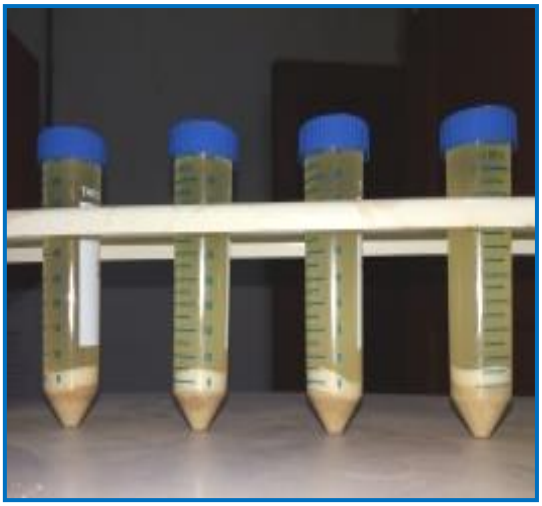
(d) Roasted watermelon seed kernel

(e) Sprouted WMSK powder

(f) Roasted WMSK powder

Plate No. 3.3 Sprouting standardization and preparation of powder

(a) Drying of sprouted WMSK



(b) WAC in a centrifuge

(c) Determination of FAC

(d) Foam capacity and stability

(e) Heating samples on a hot plate

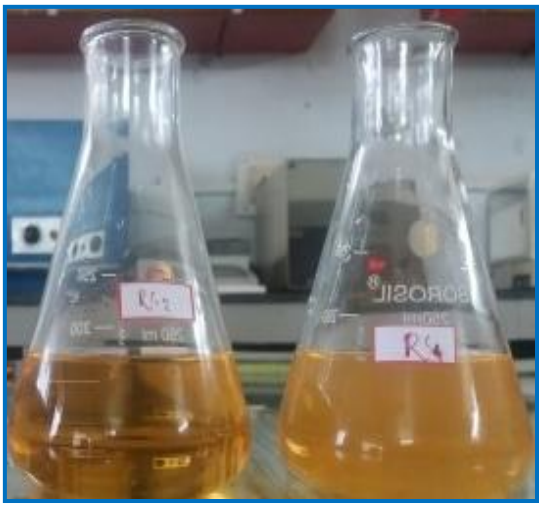
(f) Oxalate content determination

Plate No. 3.4 Functional and anti-nutritional quality determination

(a) Ether extraction (Fat content)

(b) Titration for crude protein

(c) Filtration of sample



(d) Phytate content determination

(e) Emulsion stability

(f) Digestion of sample (Protein)

Plate No. 3.5 Analysis of nutritional composition

(a) Malt powder (Ragi : watermelon)

(b) Prepared beverage of malt mix

Plate No. 3.6 Beverage preparation for sensory

(a) Normal watermelon seed

(b) Soaked watermelon seed

(c) Shelled watermelon seed

(d) Shelled watermelon seed kernel

Plate No. 3.7 Shelling of WMS in centrifugal sheller

Chapter-4

RESULTS AND DISCUSSION

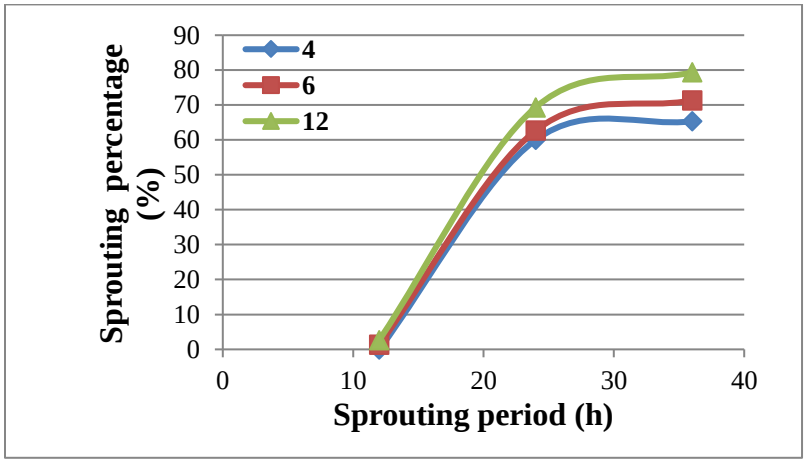
Effect of different unit operations like sprouting, roasting on proximate composition, functional and anti-nutritional properties of watermelon seed kernel has been studied. Shelling performance of seeds as influenced by soaking and sprouting has been evaluated. Nutritional and sensory evaluation of blended malt beverages prepared out of ragi and watermelon seed kernels have been carried out. The data obtained have been compiled, analyzed and the results have been discussed in this chapter.

4.1 Standardization of sprouting process of watermelon seed kernel

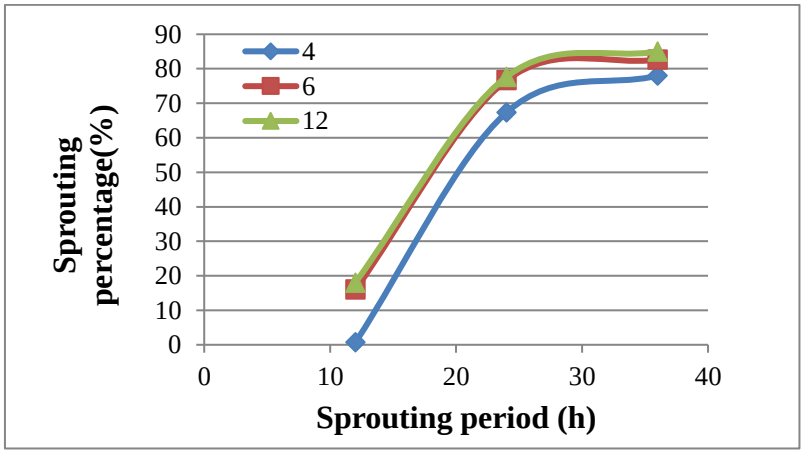
The process of sprouting is a two step method consisting of soaking followed by sprouting. The process has been standardized for maximum emergence of sprouts up to 2mm length by soaking the WMSK in both normal and warm water (40ºC). Table 4.1 summarizes the results in percentage sprouting at various soaking (4, 6 and 12h) and sprouting (12, 24, 36 and 48h) period. It is observed that sprouting percentage increased with increase in both soaking and sprouting period. The increase was higher for the samples soaked in warm water irrespective of the soaking and sprouting period. After 24h sprouting period the sprouting percentage could be more than 60%. This value increased up to 80% in normal water and 93% in warm water soaked samples. Table 4.1 shows the results of two-factor ANOVA with three replication of each experimental combination. There is significant difference ($p<0.05$) among the different classes of the factors, soaking period (4, 6 and 12h) and sprouting period (12, 24, 36 and 48h). The interactive effect was also found to be significant ($p<0.05$). However, the comparison among the classes of both the factors through critical difference indicated that the percentage sprouting in sample soaked for 6h in warm water did not differ significantly from that soaked for 12h in warm water. Overall analysis of standardization of sprouting process indicated that a combination of 12h soaking in normal water followed by 48h sprouting period and 6h soaking in warm water followed by 48h sprouting period will result in more than 85 and 92% sprouting respectively.

Table 4.1 Effect of soaking and sprouting period on sprouting percentage of watermelon seed kernel

Soaking period (h)	Normal water					Warm water				
	Sprouting period (h)					Sprouting period (h)				
	12	24	36	48	Avg.	12	24	36	48	Avg.
4	0.00	60.00	65.33	69.33	48.67	0.67	67.33	78.00	80.00	56.50
6	1.33	62.67	71.33	80.00	53.83	16.00	76.67	82.67	92.33	66.92
12	2.67	69.33	79.33	86.67	59.50	18.00	77.67	85.00	93.33	68.50
Avg.	1.33	64.00	72.00	78.67	D_a=2.38 / CD_b=2.75	11.56	73.89	81.89	88.56	CD_a=2.29 / CD_b=2.64



a) Sprouting percentage in normal water soaking



b) Sprouting percentage in warm water soaking

Fig. 4.1 Effect of soaking and sprouting period on sprouting percentage of watermelon seed kernel for normal (a) and warm (b) water

4.2 Effect of sprouting and roasting on quality characteristics of seed kernel

After standardizing the sprouting process, the sprouted and non-sprouted WMSK was dried at 60ºC up to equilibrium moisture content. Samples were roasted at 100ºC for 0.5, 1, 1.5 and 2minutes. The seeds were powdered and sieved through 60 mesh sieve and analyzed for proximate composition, functional properties and anti-nutritional components. The results are discussed in the following section.

4.2.1 Effect of sprouting and roasting on proximate composition of seed kernel

The proximate composition of the powder obtained from normal, sprouted and roasted kernels are presented in Table 4.2. The moisture content of roasted sample was significantly lower than normal (3.41±o.34%) and sprouted samples (5.78±0.36%). The moisture content of roasted sample decreased with increase in time of roasting (2.71±0.15 to 1.47±0.50%). All other components have been estimated on moisture free basis for a better comparison.

The proximate composition for normal kernel powder was 31.97±0.44% protein, 42.66±1.43% fat, 1.97±0.18% fiber, 2.83±0.30% ash and 20.57±1.80% carbohydrate. The major increasing effect of sprouting was seen on protein, ash, fiber and ascorbic acid. The increase in protein could be due to increase in free amino acids and peptides (Murugkar *et al*, IJFANS, 2013) or could be attributed to increase in soluble protein by proteolytic activity of enzymes during sprouting (Abu EI-Garion and Abdalla, 2007). The significant reduction in carbohydrate was presumably caused by starch digestion through amylolytic enzymes. The increase in respiration rate during germination brings about the release of energy from the breakdown of carbon compounds. On sprouting, the fiber, ash and ascorbic acid was found to increase substantially from normal seed powder as evident from one-way ANOVA (Appendix B_3 to B_5). The increase in fiber content is attributed to the emergence of vegetative part during sprouting.

No significant deviation in protein, fiber, carbohydrate and ash content of roasted sample could be observed from those of normal sample. However, all these values decreased in samples roasted for more time. The variation in the protein fractions observed may be the consequence of changes of the molecular mass of different samples. Roasting for 1min or more reduced the fat content which might be due to volatization or melting out of the fat. But this is useful for product with less fat

and long storage stability requirement (Igbedioh *et al*, 1994). With increase in roasting time there was significant reduction in ascorbic acid as it is highly sensitive to heat. These results agree with those found in groundnut (Abu EI-Garion and Abdalla, 2007) and watermelon seed (Kiin-Kabari and Akusu, 2014).

Table 4.2 Effect of sprouting and roasting on proximate composition* of watermelon seed kernel powder

Parameters	Samples					
	NS	SS	RS_1	RS_2	RS_3	RS_4
Protein (%)	$31.97±0.44^{c}$	$33.45±0.4^{d}$	$31.29±0.71^{bc}$	$31.24±0.56^{bc}$	$30.45± 0.16^{b}$	$28.60±0.74^{a}$
Fat (%)	$42.66±1.43^{a}$	$41.42±1.22^{a}$	$42.47±0.51^{a}$	$41.58±1.06^{b}$	$41.19± 0.96^{b}$	$40.94±0.80^{b}$
Fiber (%)	$1.97 ± 0.18^{b}$	$8.01±0.36^{d}$	$1.71±0.22^{ab}$	$1.24±0.21^{c}$	$1.42±0.13^{a}$	$1.01± 0.93^{c}$
Ash (%)	$2.83±0.30^{b}$	$5.95±0.40^{c}$	$2.65±0.53^{b}$	$2.12±0.15^{ab}$	$2.09±0.22^{ab}$	$1.91±0.30^{a}$
Carbohydrate (%)	$20.57±1.80^{b}$	$11.16 ±1.62^{a}$	$21.88±1.17^{bc}$	$23.82±0.67^{c}$	$24.85±0.80^{c}$	$27.54±1.65^{d}$
Ascorbic acid (mg/100g)	$18.0 ±0.81^{c}$	$29.52±0.94^{d}$	$18.97±0.26^{c}$	$18.60±0.33^{c}$	$15.01±0.51^{b}$	$11.64±0.59^{a}$
Moisture Content (%db)	$3.41 ± 0.34^{c}$	$5.78± 0.36^{d}$	$2.71±0.15^{b}$	$1.66± 0.05^{a}$	$1.56±0.36^{a}$	$1.47± 0.50^{a}$

*Moisture free basis calculations

Different superscript in data along the row indicates significant difference between the groups.

NS= Normal WMSK powder sample; SS= Sprouted WMSK powder sample; RS_1, RS_2, RS_3 and RS_4 are the roasted WMSK powder sample for 0.5, 1, 1.5 and 2 minutes of roasting period respectively.

4.2.2 Effect of sprouting and roasting on functional properties of seed kernel

Table 4.3 shows the effect of sprouting and roasting on functional properties. The functional properties for normal seed kernel powder was 112.17±0.57% WAC, 123.33±0.59% FAC, 71.35±0.46% ES, 19.40±0.36% FC and 12.27±0.42% FS. On sprouting the WAC (%) and FAC (%) improved significantly ($p<0.05$) indicating the ability of powder to absorb water and oil respectively. This could be due to increased protein content during sprouting and protein sub-units are known to have more water binding ability. FAC is critical in determining the flavor retention in food material. Foam capacity and foam stability of sprouted kernel powder were significantly higher than normal seed which suggest its use as a whipping or aerating agent in food system. ES is important for stabilization of additives in development of food product

like beverages and cakes etc. On the contrary the roasted samples showed gradual decrease in WAC, FAC, FC and FS with increase in time of roasting and have significant difference from those of sprouted sample (ANOVA Table; Appendix C_1 to C_5). Heat treatment in form of roasting resulted in reduction of all these properties may be explained due to the fraction of insoluble protein. However, the ES value of roasted samples improved with time of roasting (74.12±0.21% to 88.61±0.42%) after 2 minutes of roasting and was lower to that of sprouted sample (87.22±0.63%).

Table 4.3 Effect of sprouting and roasting on functional properties of watermelon seed kernel powder

Sample	Parameters				
	WAC (%)	**FAC (%)**	**ES (%)**	**FC (%)**	**FS (%)**
NS	112.17±0.57^{a}	123.33±0.59^{c}	71.35±0.46^{a}	19.40±0.36^{d}	12.27±0.42^{d}
SS	135.37±0.60^{f}	135.57±0.40^{f}	87.22±0.63^{e}	24.83±0.21^{e}	18.77±0.40^{e}
RS_1	124.90±0.85^{c}	130.73±0.64^{e}	74.12±0.21^{b}	15.07±0.31^{c}	10.10±0.46^{c}
RS_2	122.03±0.35^{d}	126.07±0.80^{d}	77.64±0.42^{c}	13.90±0.46^{b}	9.72±0.64^{b}
RS_3	119.33±0.42^{c}	120.50±0.75^{b}	80.01±0.75^{d}	12.66±0.54^{a}	8.66±0.58^{ab}
RS_4	118.17±0.38^{b}	110.03±0.42^{a}	88.61±0.42^{f}	11.93±0.87^{a}	8.06±0.97^{a}

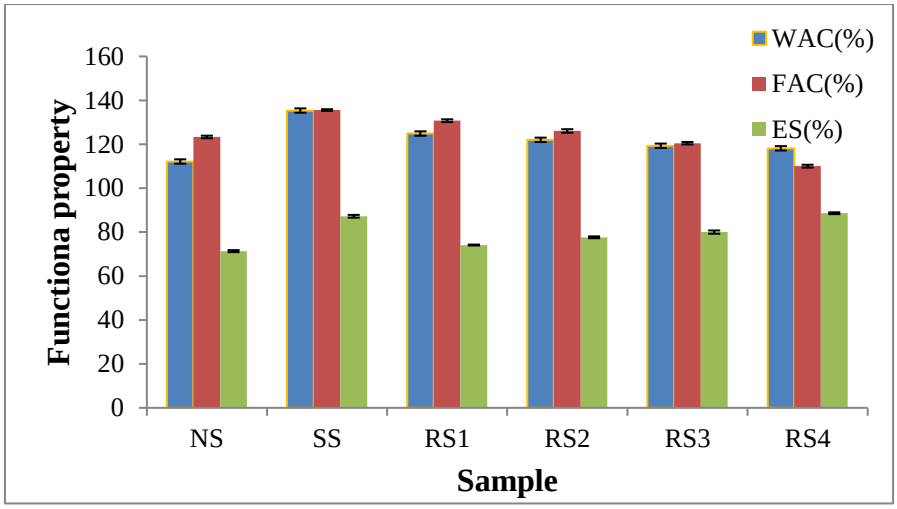
Different superscript in data along the column indicates significant difference between the groups.

NS= Normal WMSK powder sample; SS= Sprouted WMSK powder sample; RS_1, RS_2, RS_3 and RS_4 are the roasted WMSK powder sample for 0.5, 1, 1.5 and 2 minutes of roasting period respectively.

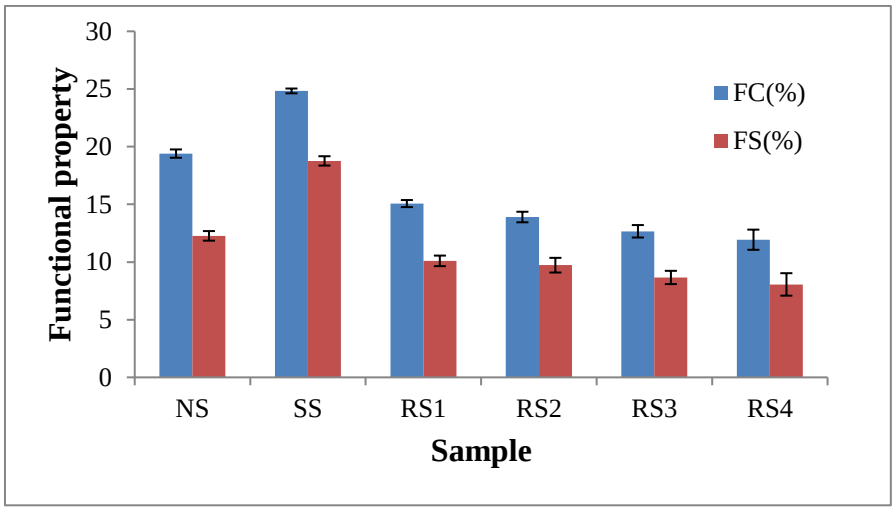
WAC= Water absorption capacity (%) ; FAC= Fat absorption capacity(%); ES= Emulsion stability(%); FC= Foam capacity (%) ; FS= Foam stability (%).

4.2.3 Effect of sprouting and roasting on anti-nutritional components

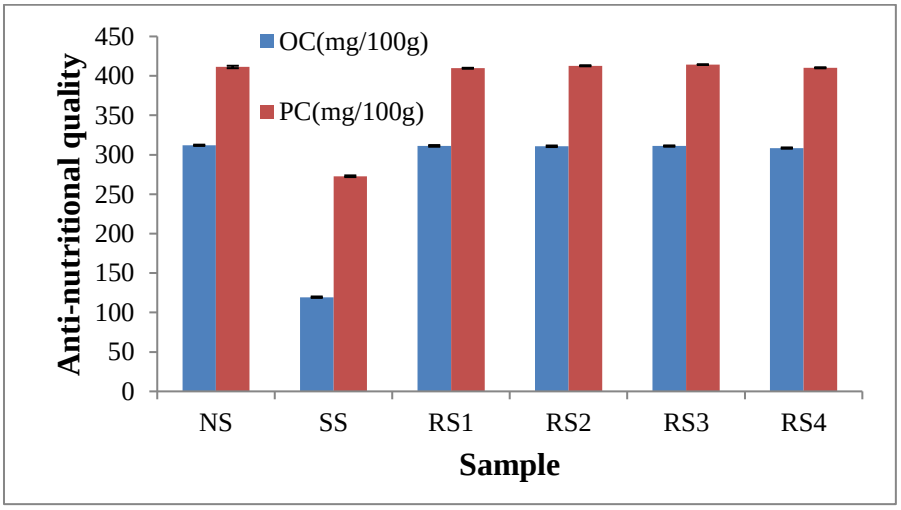
The quantitative data of anti-nutritional components are shown in Table 4.4. The unprocessed WMSK powder contained 311.99±0.80mg/100g oxalic acid and 411.27±1.54mg/100g phytic acid respectively. Oxalates are regarded as undesirable constituents of the diets, reduces assimilation of calcium favoring the formulation of renal calcium. It is observed from Table 4.4 that on sprouting the oxalic acid content decreased significantly (ANOVA-Appendix D_1) to 119.42±0.89mg/100g, where as the roasted samples did not have any significant change except the sample with 2min roasting (308.46±0.78mg/100g). This is probably because during sprouting oxalate oxidize and gets activated which breaks down oxalic acid in to carbon dioxide, hydrogen peroxide and releases calcium (Illett, 1998).



a) Effect of sprouting and roasting on WAC, FAC and ES



b) Effect of sprouting and roasting on FC and FS



c) Effect of sprouting and roasting on anti-nutritional qualities

Fig. 4.2 Effect of sprouting and roasting on functional and anti-nutritional qualities of watermelon seed kernel powder

The phytic acid content of sprouted seed kernel powder was significantly ($p<0.05$) less (272.74±1.06mg/100g) than the normal seed powder. Leaching out effect during soaking and the increase in phytase activity during sprouting could be responsible for the loss of phytate. However, dry heat treatment to roasted samples was not effective in reducing phytate content and the values ranged between 409 to 410mg/100g. The phenomena may be explained this way that sprouting is a catabolic process that supplies important nutrients to the growing plant through hydrolysis of reserve nutrients. Phytic acid is a source of phosphorous and cations during sprouting. Thus reduction in phytic acid may enhance the mineral bio availability of the seed powder (Ruiz and Bressani, 1990).

Table 4.4 Effect of sprouting and roasting on anti-nutritional components of watermelon seed kernel powder

Sample	Parameter	
	Oxalic acid (mg/100g)	**Phytic acid (mg/100g)**
NS	$311.99±0.80^{c}$	$411.27±1.54^{c}$
SS	$119.42±0.89^{a}$	$272.74±1.06^{a}$
RS_1	$311.22±1.05^{c}$	$409.63±0.59^{b}$
RS_2	$310.73±0.97^{c}$	$412.80±0.65^{cd}$
RS_3	$310.99±0.79^{c}$	$414.28±0.31^{d}$
RS_4	$308.46±0.78^{b}$	$410.26±0.64^{bc}$

Different superscript in data along the column indicates significant difference between the groups.

NS= Normal WMSK powder sample; SS= Sprouted WMSK powder sample; RS_1, RS_2, RS_3 and RS_4 are the roasted WMSK powder sample for 0.5, 1, 1.5 and 2 minutes of roasting period respectively.

4.3 Shelling characteristics of watermelon seeds

The performance evaluation of the centrifugal sheller available in the dept. of APFE was carried out for watermelon seeds for three operating speeds (1500, 1750 and 2000rpm) and three different moisture contents (15±1, 20±1 and 25±1 % db). All these set of operation were carried out for both soaked and sprouted samples. The centrifugal sheller was fed with known quantity of seeds and the shelling time was noted for each experiment. The shelling operation was continued in successions as shown in Appendix E_3. The husk, shelled, unshelled, shelled broken and unshelled

broken samples were weighed separately from which the performance indicators i.e. capacity, shelling efficiency, broken percentage and whole kernel recovery were calculated. Table 4.5 summarizes the result of shelling characteristics at different moisture content and shelling speed for both soaked and sprouted seeds. The capacity was ranged between 2 to 3 kg/h and did not vary significantly. The performance indicators varied with all these process parameters which are discussed in following sections. The samples roasted for 5 minutes and 10 minutes at 100ºC were subjected to shelling test. It was observed that both the samples produced a very high percentage of broken (26 and 39%). Correspondingly the WKR was found to be very less (13 to 17%) in spite of relatively acceptable shelling efficiency. Therefore, further study on shelling of roasted sample was ruled out.

4.3.1 Effect of seed moisture content and shelling speed on shelling efficiency

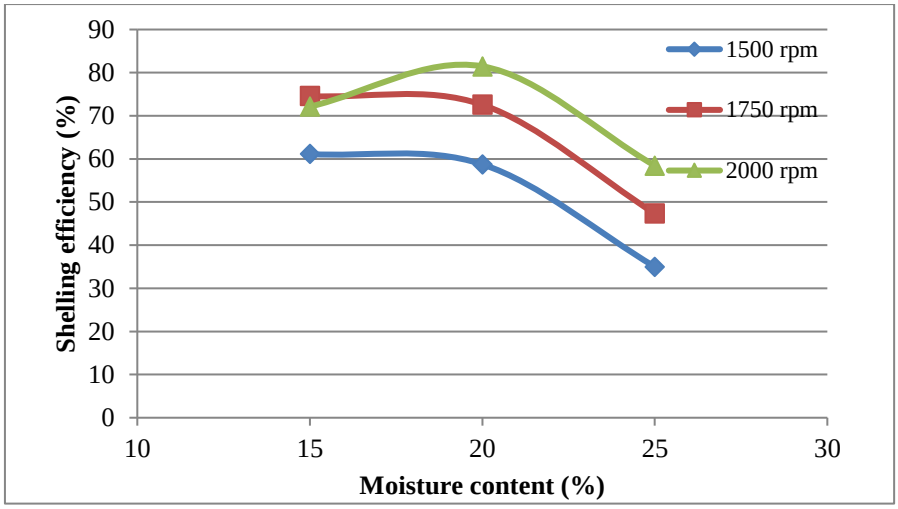
It is observed from Table 4.5 that the shelling efficiency of any combination was invariably higher in sprouted sample than soaked sample. This result gives a clear conclusion that naturally created openings or crack in the husk of sprouted seed makes the shelling operation easy, hence higher shelling efficiency. In soaked sample the minimum shelling efficiency was 35% at moisture content of 25% and 1500 rpm and the maximum shelling efficiency was 81.46% at moisture content 20% & 2000 rpm. The general trend indicated that shelling efficiency increased with increasing shelling speed but reducing moisture content. This is attributed to the higher impact force at higher speed and loosening of husk at low moisture content due to contraction. The significant effect of these two factors on performance indicators at individual and interactive level is shown in details in (Appendix E_1) through two-factor analysis of variance without replication. These results corroborate the precious finding for melon seeds (Sobowale *et al*, 2015 and Daniel *et al*, 2015). Similar trend has been observed for sprouted seeds in Table 4.5 and Fig 4.4.a. The corresponding ANOVA can also be verified from Appendix $E_{2.}$ The only exception in the trend observed in both soaked and sprouted sample was a lower shelling efficiency at 15% moisture content and 2000 rpm (72.12 and 71.58 respectively). This could be due to brittleness of the seeds at low moisture content and high shelling speed giving rise to more unshelled seed breakage.

Table 4.5 Test results for performance indicators of watermelon seeds in the centrifugal sheller

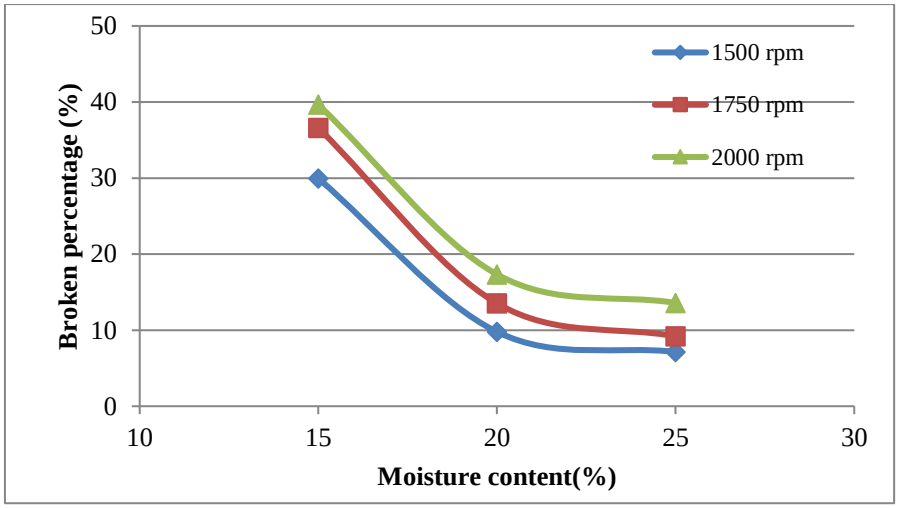
Moisture content (%)	Shelling speed (rpm)	Shelling efficiency (%)	Percentage of broken seed (%)	Whole kernel recovery (%)	Capacity (kg/h)
Soaked sample					
15±1	1500	61.14	29.95	13.08	2.22
	1750	74.58	36.59	8.43	2.27
	2000	72.12	39.64	6.76	2.99
20±1	1500	58.74	9.78	42.94	2.17
	1750	72.56	13.53	58.16	2.17
	2000	81.46	17.33	66.53	2.24
25±1	1500	35	7.14	28.3	2.59
	1750	47.35	9.19	50	2.61
	200	58.44	13.58	48.14	2.22
Sprouted sample					
15±1	1500	65.78	20.64	32.57	2.68
	1750	75.61	25.85	38.38	2.59
	2000	79.95	31.59	10.43	2.27
20±1	1500	60.64	7.63	49.92	2.95
	1750	74.80	8.42	69.13	2.69
	2000	73.54	26.2	37.84	2.22
25±1	1500	60.48	6.35	51.25	3.02
	1750	69.31	6.7	67.7	2.4
	2000	71.58	13.95	42.36	2.94
Roasted sample (5 min)	1750	58.76	26.53	17.82	2.32
Roasted sample (10 min)	1750	74.35	39.13	13.95	2.46

4.3.2 Effect of seed moisture content and shelling speed on percentage broken seeds

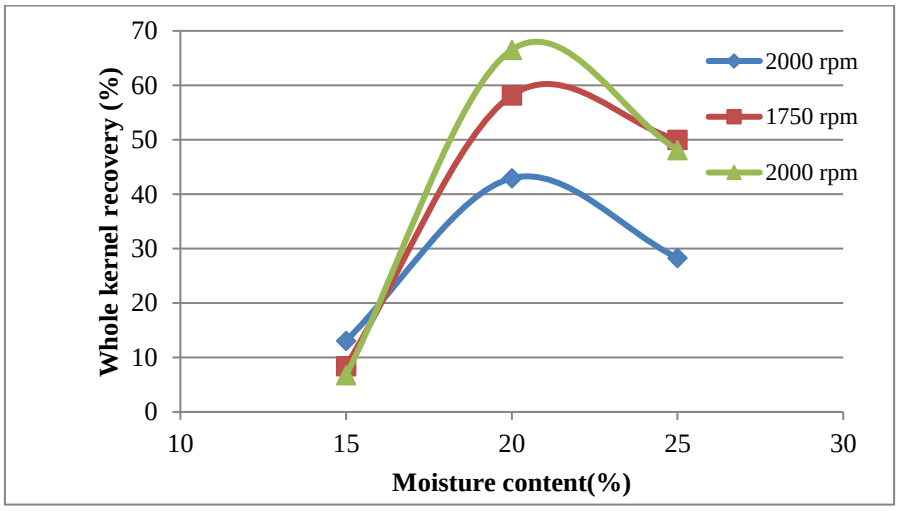
The effect of seed moisture content and shelling speed on percentage broken seed is presented in Table 4.5 for soaked sample (Fig. 4.3.b) and sprouted sample (Fig. 4.4.b). The range of percent broken varies from 6.35% to 39.64%. On an average the percent broken was less in sprouted seed than soaked seed samples for any given set of process parameters. There was an increasing trend of breakage with increasing speed and decreasing moisture content. However a substantial breakage percentage at 15% moisture content could be due to higher brittleness. The general observations on trend of broken percent in the present investigation is in agreement with precious research findings (Sharma et al, 2013) for tung fruits.



a) Shelling efficiency vs. Moisture content

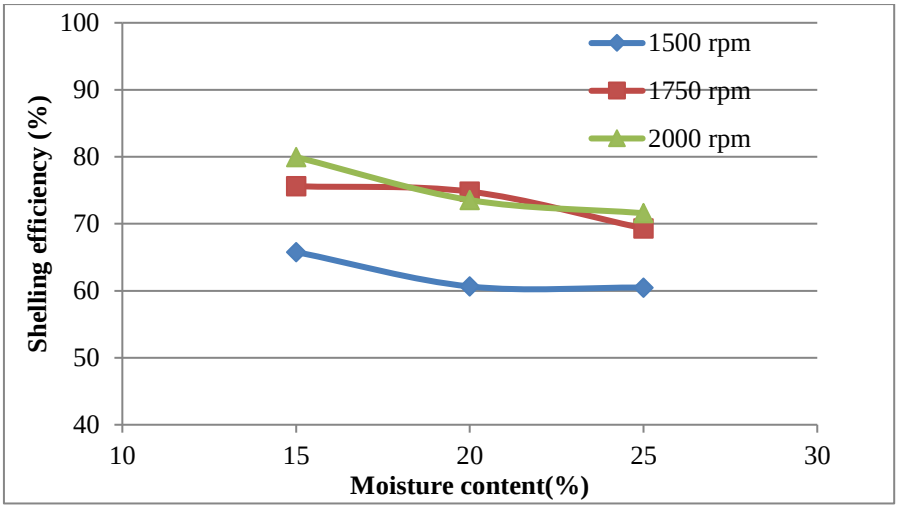


b) Broken percentage vs. Moisture content

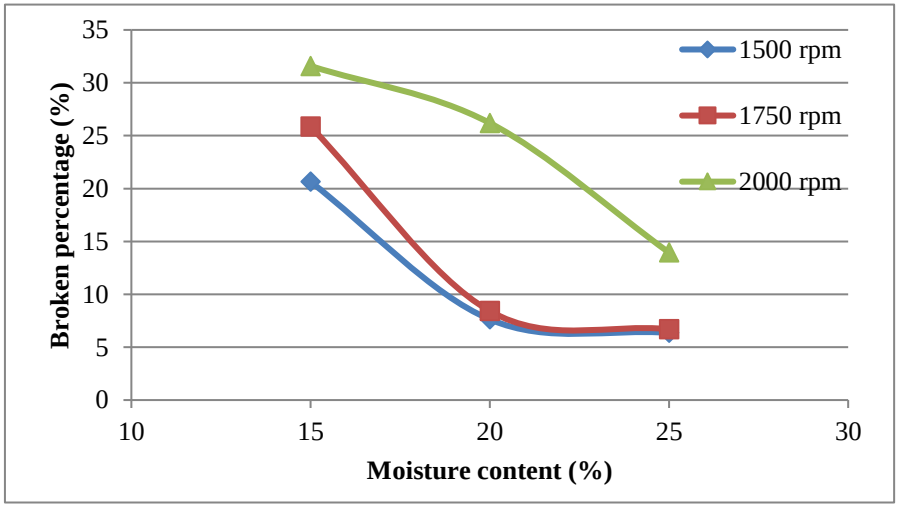


c) WKR vs. Moisture content

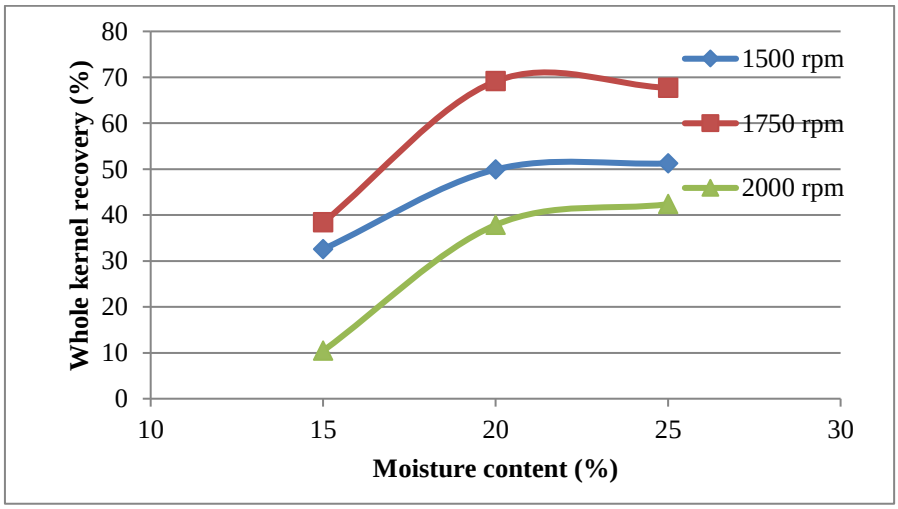
Fig 4.3 Effect of moisture content and shelling speed on (a) shelling efficiency, (b) broken percentage and (c) whole kernel recovery for soaked sample



a) Shelling efficiency vs. Moisture content



b) Broken percentage vs. Moisture content



c) WKR vs. Moisture content

Fig 4.4 Effect of moisture content and shelling speed on (a) shelling efficiency, (b) broken percentage and (c) whole kernel recovery for sprouted sample

4.3.3 Effect of seed moisture content and shelling speed on whole kernel recovery

In shelling process WKR is the most vital parameter among all performance indicators, because this is the component which has marketability as per consumer requirement. The WKR of the present research work summarized in Table 4.5 and is depicted pictorially in Fig. 4.3.c (Soaked sample) and in Fig. 4.4.c (Sprouted sample). Though a significant higher WKR was observed for most of the sprouted samples as compared to soaked ones, the trend were not similar. In soaked samples the WKR was found to give highest values at 20% moisture content irrespective of shelling speed. This could be due to higher breakage of shelled seeds in these conditions. Further at any moisture content with increase in shelling speed the WKR increased. However maximum WKR of 66.53% was obtained at 20% moisture content at 2000 rpm for soaked sample. In case of sprouted samples though wide variation in WKR (10.43% TO 69.13%) was observed, the pattern was definite. Fig. 4.4.c Indicated that WKR increased from 15 to 20% moisture content and then it leveled off or slightly decreased at 25% moisture content. Similarly the value increased from 1500 rpm to 1750 rpm and reduced significantly at 2000rpm. This is due to cracking of shelled kernels at higher impact force at shelling speed. The WKR was maximum (69.13%) at moisture content of 20±1% and shelling speed of 1750 rpm for sprouted seed.

Results obtained showed that the machine can effectively shell watermelon seeds and the seed moisture content and the speed of the shelling machine affected the performance indicators. The shelling efficiency increases with an increase in moisture content and irrespective of shelling speed. However, maximum WKR of 66.53% was obtained at 20% moisture content at 2000 rpm for soaked sample. The WKR was maximum (69.13%) at moisture content of 20±1% and shelling speed of 1750 rpm for sprouted seed.

4.4 Preparation and evaluation of blended malt

It was inferred from previous experiments that sprouted WMSK powder has great potential for addition to food system not only as supplement but also as functional agents. Particularly the properties like WAC, FAC, ES and foaming characteristics have been found to be significantly higher than the normal WMSK powder which leads to the possibility of preparation of a novel beverage. Therefore an attempt has been made to prepare blended malt beverage from sprouted WMSK

powder blended with malted ragi in order to bring in balanced diet rich with health promoting factors. The proportion of sprouted WMSK powder has been kept for ragi:WMSK as 70:30, 60:40, 50:50 and 0:100. The results of nutritional composition of these malt powder mixes are depicted in Table 4.6. As expected with increase in WMSK powder proportion from 30% to 100%. The protein, fat, fiber and ash content steadily increase from (21.18±0.55to 33.45±0.44%), (14.53±0.84 to 41.42±1.22%), (3.49±0.53 to 8.01±0.36%) and (1.8±0.17 to 5.95±0.40%) respectively. On the contrary a reducing trend was observed for carbohydrate. This is due to obvious fact of higher protein, fat, fiber and ash content and low carbohydrate content of sprouted WMSK powder. The significance of differences in mean values among variants is given in (ANOVA-Appendix F_1 to F_6).

Table 4.6 Effect of various proportion of blended malt on nutritional composition*

Parameters	Samples			
	S_1(70:30)	**S_2(60:40)**	**S_3(50:50)**	**S_4(0:100)**
Protein (%)	21.18 ± 0.55^{a}	24.54 ± 0.88^{b}	26.87 ± 0.96^{c}	33.45 ± 0.44^{d}
Fat (%)	14.53 ± 0.84^{a}	17.10 ± 0.39^{b}	25.83 ± 0.59^{c}	41.42 ± 1.22^{d}
Fiber (%)	3.49 ± 0.53^{a}	3.92 ± 0.43^{a}	4.07 ± 0.26^{a}	8.01 ± 0.36^{b}
Ash (%)	1.80 ± 0.17^{a}	2.61 ± 0.43^{ab}	3.63 ± 0.64^{b}	5.95 ± 0.40^{c}
Carbohydrate (%)	58.99 ± 1.15^{d}	51.83 ± 0.98^{c}	39.63 ± 1^{b}	11.16 ± 1.62^{a}
Moisture Content (%)	6.29 ± 0.32^{bc}	6.78 ± 0.39^{c}	6.03 ± 0.21^{b}	5.78 ± 0.36^{d}

* Moisture free basis calculations
Different superscript in data along the row indicates significant difference between the groups

The different proportion of malt powder were used to prepare four variants of blended malt beverage and subjected to sensory evaluation. The means of scores for sensory attributes like colour, flavor, taste and consistency obtained from 20 panelists are presented in Table 4.7. Overall acceptability which was calculated through composite scoring using weight factors for individual attributes was the basis for selection of the best proportion. Though the beverage prepared with only sprouted WMSK powder (S_4) scored highest (8.02), the ANOVA revealed that there was no significant difference between S_3 (50:50) and S_4 (0:100). Considering the nutritional composition the sample S_3 (50:50) also has more balanced composition as far as presence of fat is concerned. However, for weaning food preparation the sample S_4 with higher fat content may also be recommended for a particular age group kids.

Table 4.7 Mean sensory score of blended malt (Ragi:Watermelon) on 9 point hedonic scale

Sample	Attributes				
	Colour	**Flavor**	**Taste**	**Consistency**	**Overall Acceptability**
S_1(70:30)	7.15±0.67[a]	6.92±0.99[a]	6.75±1.03[a]	7.10±1.07[a]	6.96±0.62[a]
S_2(60:40)	7.65±0.61[b]	7.27±1.02[ab]	7.20±0.80[a]	7.32±0.95[ab]	7.36±0.64[ab]
S_3(50:50)	7.75±0.84[b]	8.17±0.61[b]	8.10±0.66[b]	7.60±1.01[ab]	7.93±0.58[b]
S_4(0:100)	8.23±0.78[c]	7.80±1.41[b]	8.07±1.36[b]	7.90±0.95[b]	8.02±0.97[b]

4.4.1 Regression analysis between theoretical and measured composition

In order to eliminate the cumbersome process of determination of proximate composition of blended mix, an attempt has been made to develop a relation between theoretical compositions vs. observed values (National institute of nutrition, 2000). For this the nutritional composition both sprouted ragi and sprouted WMSK powder has been determined analytically. Then the composition of different blends has been estimated considering the proportion as weight factors. These theoretical values have been regressed with observed values and the equations have been summarized in Table 4.8. It is evident that these two variables are related linearly for all the compositions with a R^2 value more than 0.9. Therefore, these statistical equations may be considered for use in absence of instrumentation.

Table 4.8 Regression analysis for calculated* and observed values for nutritional composition of blended malt

Parameters	**Best fit**	**R^2**	**Equation**
Protein	Linear	0.9893	Y=1.2074X+2.8516
Fat	Linear	0.9097	Y=1.545X-5.7245
Fiber	Linear	0.9279	Y=0.8923X-0.965
Ash	Linear	0.9965	Y=3.7431X-12.339
Carbohydrate	Linear	0.9779	Y=1.4721X-33.519

***National institute of nutrition (NIN)**

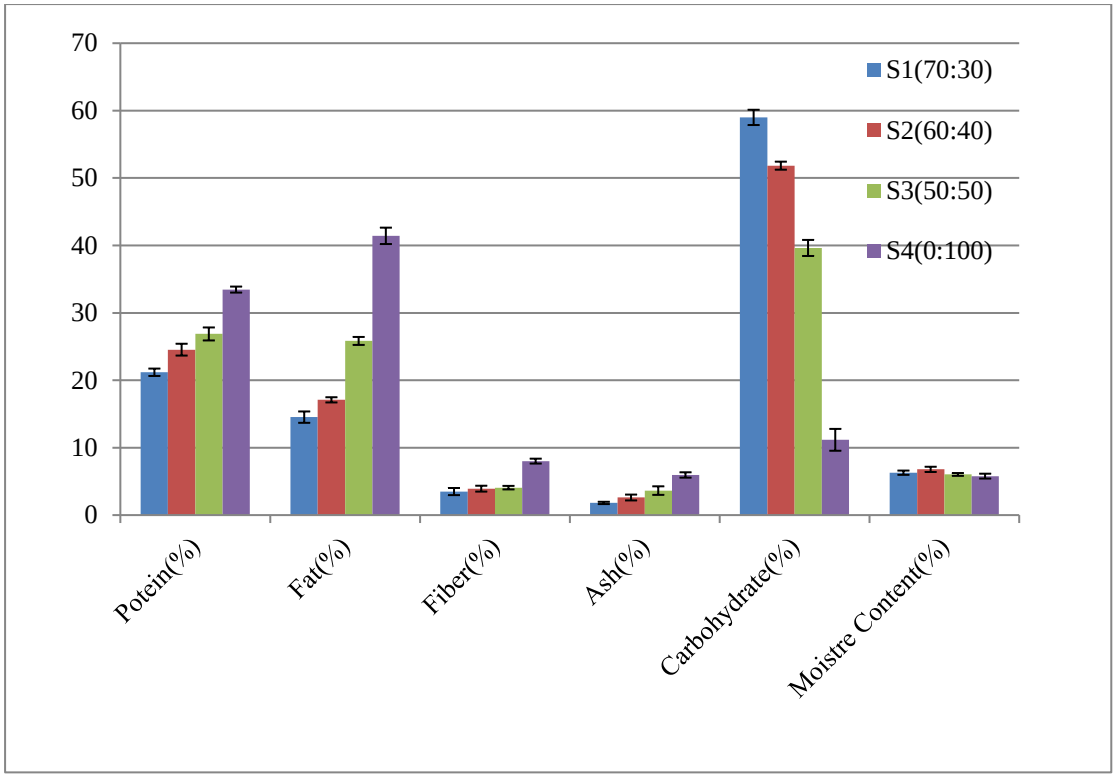


Fig. 4.5 Effect of various proportion of blended malt on nutritional composition

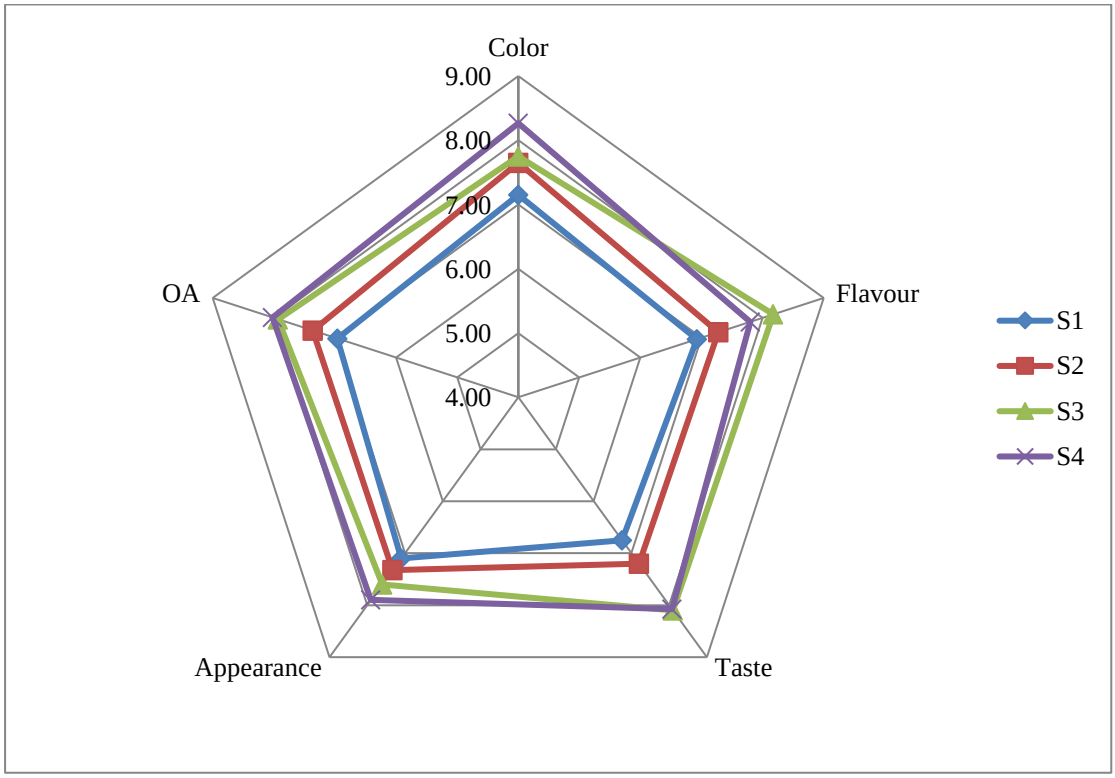


Fig. 4.6 Mean sensory score of blended malt on 9 point hedonic scale

Chapter-5

SUMMARY AND CONCLUSION

The knowledge of the nutritive and the anti-nutrient content of various parts of these fruits will encourage their consumption in diverse ways and re-utilization of the vast amount of seeds discarded as waste for human food, animal feed and fertilizer. Much has been reported on the nutritional value of watermelon seeds and how it can be used to effectively prevent nutritional deficiency in man as well as treat nutritional diseases. The seeds which are often the waste part of the fruits have not generally received much attention with a view to being used or recycled rather than discarded. Interestingly the seeds of watermelon have higher protein, fat, vitamins, minerals and other essential nutrient activity. It is therefore necessary to evaluate the nutritional and anti-nutrients contents of these fruits and their waste materials so that the knowledge derived can be used to encourage adequate consumption of fruits and re-utilization of the seeds in possible value added applications.

Sprouting has been claimed to improve the nutritional quality of seeds and cereals by increasing the contents and availability of essential nutrients and lowering the levels of anti-nutrients. Sprouting can increase protein content, mineral bioavailability and ascorbic content. Sprouting is cheap and more effective in improving nutritional value. It can be incorporated in mixes to contribute to the nutrition of people. This processing treatment is effective in eliminating the anti-nutritional factors in foods. Roasting can enhance flavor through caramelization and Maillard browning on the surface of the food. It is also known to increase the antioxidant activity of the food product

Manual method of removal of cotyledon from the seed is tedious and time consuming. Traditionally, the seeds are removed from the rind and then allowed to dry outside in the sun, once dried the seeds are shelled manually and then milled into flour. Water melon seeds are among the under-utilized fruit by-products, though technology exists for decorticating the seeds, only a small proportion of the seed is commercially processed because of unavailability of a low cost machine

Keeping all these facts in view the present work aimed at the following objectives:

- To study the effect of sprouting and roasting on functional and anti-nutritional qualities of watermelon seeds.
- To study the effect of operational speed and seed conditions on shelling of watermelon seeds in a centrifugal shelling device.
- To prepare blended malt powder from sprouted ragi and watermelon seeds and to evaluate its quality.

In order to conduct the experiment in a systematic and efficient manner the entire experimental work was divided into various components. Before starting the experiment the independent variables and their levels were decided. The relevant parameters through which the inference of the experiment was to be predicted were selected as dependent parameters. Such plans were designed objective wise and are presented below.

Objective -1

Effect of sprouting and roasting on functional and anti-nutritional quality

Independent parameter:

4. Normal Seeds
5. Sprouted Seeds
6. Roasted Seeds (Temperature-100ºC, Time- 0.5min, 1min, 1.5min, 2min)

Fixed parameter: Seed Powder (60 Mesh sieve)

Drying 50±2ºC (Tray dryer)

Dependent parameter:

4. Moisture Content(%db)
5. Functional Quality
    - Water absorption capacity (%)
    - Fat absorption capacity (%)
    - Emulsion Stability (%)
    - Foam Stability (%)
    - Foam Capacity (%)
    - Ascorbic acid (mg/100g)

6. Anti-nutritional Quality
    - Phytic acid (mg/100g)
    - Oxalic acid (mg/100g)

Objective -2

Effect of operational speed and seed conditions on shelling of watermelon seeds

Independent variable:

3. Shelling Speed (1500rpm, 1750rpm, 2000rpm)
4. Moisture Content (15%, 20%, 25% db)

Dependent variable:

5. Shelling Efficiency (%)
6. Percentage of broken seed (%)
7. Whole kernel recovery (%)
8. Capacity(Kg/h)

Objective -3

Preparation and evaluation of blended malt powder

Independent variable:

2. Ragi:Watermelon(70:30, 60:40, 50:50, 0:100)

Fixed parameters: Sprouting: 2mm
Drying: 50±2ºC

Dependent variable:

4. **Moisture content**
5. **Nutritional Quality**
    - Protein (%)
    - Fat (%)
    - Carbohydrate (%)
    - Ash (%)
    - Fiber (%)
6. **Sensory Evaluation**
    - Colour
    - Flavor
    - Taste
    - Consistency
    - Overall Acceptability (By composite scoring)

Standardization of sprouting process of watermelon seed kernel was done to obtain maximum sprouting percentage. The kernels were soaked for 4h, 6h and 12h in both normal and warm water. The soaked kernels were subjected to sprouting period of 12h, 24h, 36h and 48h respectively in a sprout maker. The samples (preconditioned watermelon seed kernel) required for different analysis was grinded separately with a mixer grinder and the powder was packed in an airtight container to prevent any gain in moisture and stored at room temperature.

For shelling test of watermelon seed in a centrifugal sheller the speed of the impeller was adjusted to the desired value by a variac attached to the motor. The pre-conditioned watermelon seed (soaked and sprouted) at the desired moisture level was fed to the centrifugal sheller. The sample with a particular moisture content was tested with different rpm (1500, 1750, 2000 rpm). After each experiment the seeds were carefully collected from the outlets.

For the preparation of blended malt powder, ragi grain and water melon seed kernel were sprouted. Sprouted ragi powder and sprouted watermelon seed kernel powder are mixed at different proportion that is 70:30, 60:40, 50:50 and 0:100 respectively and packed in a airtight container for further use. However in order to ease the calculation the proximate composition has been estimated theoretically (NIN, 2012) and was regressed to that of observed values to develop suitable mathematical equation.

Quality analysis was performed by the functional properties, anti-nutritional qualities; proximate composition of watermelon seed powder and sensory evaluation of blended malt. The sensory evaluation was done using a nine point hedonic scale following the procedure of ISI. The attributes for the products under study considered were colour, flavor, taste and consistency. However, the overall acceptability was estimated using composite scoring. A panel of 20 semi trained members evaluated the prepared the blended malt (ragi:watermelon).

The data obtained during the course of investigation were analyzed and the salient conclusions are given below:

1. Standardization of sprouting process indicated that a combination of 12h soaking in normal water followed by 48h sprouting period and 6h soaking in

warm water (40ºC) followed by 48h sprouting period will result in more than 85% and 92% sprouting respectively.

2. On sprouting, the fiber, ash and ascorbic acid was found to increase substantially from normal WMSK powder (8.01±0.36%, 5.95±0.40% and 29.52±0.94% respectively). On sprouting the WAC (135.37±0.60%), FAC (135.57±0.40%), ES (87.22±0.63%), FC (24.83±0.21%) and FS (18.77±0.40%) improved significantly
3. With increase in roasting time there was significant reduction in ascorbic acid as it is highly sensitive to heat. The roasted samples showed gradual decrease in WAC, FAC, FC and FS with increase in time of roasting and have significant difference from those of sprouted sample. On the contrary roasted sample was shown to have good emulsion stability.
4. The unprocessed WMSK powder contained 311.99±0.80mg/100g oxalic acid and 411.27±1.54mg/100g phytic acid respectively. On sprouting the oxalic acid content and phytic acid content decreased significantly to 119.42±0.89mg/100g and 272.74±1.06mg/100g respectively. Dry heat treatment to roasted samples was not effective in reducing oxalic acid content and phytic acid content significantly.
5. The shelling efficiency increased with a decrease in moisture content and increase in shelling speed. But the shelling efficiency of any combination was invariably higher in sprouted sample than soaked sample.
6. On an average the percent broken was less in sprouted seed than soaked seed samples for any given set of process parameters. There was an increasing trend of breakage with increasing speed and decreasing moisture content.
7. Maximum WKR of 66.53% was obtained at 20±1% moisture content at 2000 rpm for soaked sample where as WKR was maximum (69.13%) at moisture content of 20±1% and shelling speed of 1750 rpm for sprouted seed.
8. Though the beverage prepared using only sprouted WMSK powder (S_4) scored highest overall acceptability (8.02), the ANOVA revealed that there was no significant difference between S_3 (ragi:WMSK, 50:50) and S_4 (ragi:WMSK, 0:100). Considering the nutritional profile, the sample S_3 (50:50) also has more balanced composition to be recommended for adult group of the society.

Chapter-6

SUGGESTIONS FOR FUTURE WORK

The following suggestions are made for the future work.

1. In the present study, the sprouted seeds have shown better shelling characteristics. Therefore, it is suggested that, further work should be carried out with a wider range of moisture content and shelling speed combinations to have elaborate result.
2. The capacity of the centrifugal sheller also needs to be increased by upgrading the machine design.
3. The storage of watermelon seed powder has been found to be difficult. So a thorough study on storage of watermelon seed powder and blended malt powder using different packaging material should be conducted.

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APPENDIX

Appendix A: Standardization of sprouting results

A_1: Sprouting percentage of WMSK in normal and warm water

The analysis was done using ANOVA (two factor-with replication)

Replicated data for soaking in normal and warm water

Sprouting percentage (%)								
	Normal water				Warm water			
Soaking period (h)	Sprouting period (h)				Sprouting period (h)			
	12	24	36	48	12	24	36	48
4	0	60	66	72	0	68	76	82
	0	62	62	70	0	70	80	78
	0	58	68	66	2	64	78	80
6	0	66	70	78	16	78	84	91
	4	60	74	78	18	72	80	94
	0	62	70	84	14	80	84	92
12	0	68	80	88	20	80	88	95
	6	74	76	84	16	75	82	92
	2	66	82	88	18	78	85	93

Analysis of critical difference for normal water soaking

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	704.666667	2	352.3333	44.04167	9.29E-09	3.402826
Columns	34256	3	11418.67	1427.333	3.61E-27	3.008787
Interaction	199.333333	6	33.22222	4.152778	0.005321	2.508189
Within	192	24	8			
Total	35352	35				

CD_a=2.38,CD_b=2.75

Analysis of critical difference for warm water soaking

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	1020.056	2	510.0278	88.27404	8.63E-12	3.402826
Columns	33940.75	3	11313.58	1958.12	8.28E-29	3.008787
Interaction	121.5	6	20.25	3.504808	0.012412	2.508189
Within	138.6667	24	5.777778			
Total	35220.97	35				

CD_a=2.29,CD_b=2.64

Appendix B: Proximate analysis result for WMSK powder

B_1: Crude protein content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
31.94	32.95	31.96	31.38	30.30	28.10
31.54	33.61	30.55	30.62	30.62	29.45
32.42	33.79	31.36	31.73	30.43	28.27

Analysis of critical difference for protein

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38.89	5	7.778	26.179	4.59731E-06	3.106
Within Groups	3.565	12	0.2970			
Total	42.45	17				

CD=0.97

B_2: Fat content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
44.32	41.42	43.04	40.41	40.60	40.69
41.87	40.21	42.07	42.47	42.30	40.29
41.80	42.64	42.29	41.86	40.67	41.84

Analysis of critical difference for fat

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7.342001	5	1.4684	1.359359	0.305802	3.105875
Within Groups	12.96258	12	1.080215			
Total	20.30458	17				

CD=1.55

B_3: Crude fiber content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
2.04	7.87	1.72	1.40	1.56	0.06
1.77	7.73	1.49	1.32	1.30	1.91
2.10	8.42	1.93	1.00	1.41	1.06

Analysis of critical difference for fiber

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	108.511	5	21.702	115.252	1.02893E-09	3.1059
Within Groups	2.260	12	0.1883			
Total	110.770	17				

CD=0.38

B_4: Ash content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
3.15	6.41	2.12	2.23	2.12	1.81
2.79	5.76	2.66	2.18	1.86	2.24
2.56	5.69	3.17	1.95	2.30	1.67

Analysis of critical difference for ash

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	34.88946	5	6.977891	61.40412	3.95E-08	3.105875
Within Groups	1.363666	12	0.113639			
Total	36.25312	17				

CD=0.60

B_5: Carbohydrate content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
18.55	11.35	21.16	24.58	25.42	29.34
22.02	12.69	23.23	23.41	23.93	26.10
21.12	9.46	21.25	23.46	25.19	27.16

Analysis of critical difference for carbohydrate

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	482.166	5	96.433	52.343	9.83023E-08	3.1059
Within Groups	22.1079	12	1.8423			
Total	504.274	17				

CD=2.41

B_6: Moisture content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
3.09	5.95	2.83	1.71	1.42	1.26
3.37	5.36	2.76	1.62	1.97	1.11
3.76	6.02	2.54	1.65	1.29	2.04

Analysis of critical difference for moisture content

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	41.52357	5	8.304714	76.83138	1.09E-08	3.105875
Within Groups	1.297082	12	0.10809			
Total	42.82065	17				

CD=0.58

B_7: Ascorbic determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
17.40	28.63	18.71	18.95	15.29	12.24
18.97	30.51	18.96	18.69	14.42	11.62
17.87	29.43	19.24	18.15	15.33	11.07

Analysis of critical difference for ascorbic acid

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	543.0536	5	108.6107	273.4952	6.28E-12	3.105875
Within Groups	4.765454	12	0.397121			
Total	547.8191	17				

CD=1.12

Appendix C: Functional property results

C_1: Water absorption capacity (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
112.8	135.3	125	122.4	119	117.9
112	136	125.7	122	119.2	118.6
111.7	134.8	124	121.7	119.8	118

Analysis of critical difference for WAC

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	916.74	5	183.35	592.50	6.28858E-14	3.10587
Within Groups	3.71	12	0.31			
Total	920.45	17				

CD=0.98

C_2: Fat absorption capacity (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
123.1	136	131.2	126	120.4	110
122.9	135.5	130	126.9	120	109.4
124	135.2	131	125.3	121.1	110.7

Analysis of critical difference for FAC

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1170.983	5	234.1966	611.8343	5.19E-14	3.105875
Within Groups	4.593333	12	0.382778			
Total	1175.576	17				

CD=1.10

C_3: Emulsion stability (%)
The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
71.44	86.7	74.34	78.07	79.27	89.06
71.76	87.05	74.11	77.64	80.76	88.23
70.85	87.92	73.92	77.23	80	88.54

Analysis of critical difference for ES

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	723.076	5	144.615	556.4267	9.15013E-14	3.10587
Within Groups	3.1188	12	0.2599			
Total	726.1954	17				

CD=0.90

C_4: Foaming capacity (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
19.7	24.6	14.8	13.8	12.95	11.2
19	25	15	13.5	13	12.9
19.5	24.9	15.4	14.4	12.04	11.7

Analysis of critical difference for FC

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	366.006	5	73.201	286.6825	4.75017E-12	3.1059
Within Groups	3.064067	12	0.2553			
Total	369.0701	17				

CD=0.89

C_5: Foaming stability (%)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
11.8	18.7	10	10.3	9.22	8.44
12.6	18.4	10.6	9.04	8.69	8.78
12.4	19.2	9.7	9.83	8.07	6.95

Analysis of critical difference for FS

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	234.275	5	46.85501	126.0202	6.1E-10	3.105875
Within Groups	4.461667	12	0.371806			
Total	238.7367	17				

CD=1.08

Appendix D: Anti-nutritional quality results

D_1: Oxalic acid content determination (mg/100g)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS1	RS2	RS3	RS4
311.68	119.62	312.43	310.73	310.14	308.95
311.39	120.19	310.69	309.76	311.14	308.88
312.90	118.45	310.54	311.69	311.7	307.56

Analysis of critical difference for oxalic acid content

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	91472.54	5	18294.51	23340.69	1.73E-23	3.105875
Within Groups	9.405638	12	0.78380			
Total	91481.94	17				

CD=1.57

D_2: Phytic acid content determination (mg/100g)

The analysis was done using ANOVA (single factor).

Replicated data for different treatment

NS	SS	RS_1	RS_2	RS_3	RS_4
410.36	273.8705	409.53	412.37	414.35	410.05
410.41	271.7578	409.09	413.55	414.54	409.74
413.05	272.5939	410.26	412.47	413.94	410.98

Analysis of critical difference for phytic acid content

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	48279.85	5	9655.97	12100.32	8.91E-22	3.105875
Within Groups	9.575915	12	0.797993			
Total	48289.43	17				

CD=1.59

Appendix E: Analysis of different shelling parameters for soaked and sprouted WMS

E_1: Analysis of different performance indicators for soaked WMS

The analysis was done using ANOVA (two-factors without replication).

Effect of different shelling speed and m.c. on different shelling parameters for soaked sample

Moisture content (%)	Shelling efficiency (%)			Broken percentage (%)			Whole kernel recovery (%)		
	Shelling speed (rpm)			Shelling speed (rpm)			Shelling speed (rpm)		
	1500	**1750**	**2000**	**1500**	**1750**	**2000**	**1500**	**1750**	**2000**
15	61.14	74.58	72.12	29.95	36.59	39.64	13.08	8.43	6.76
20	58.74	72.56	81.46	9.78	13.53	17.33	42.94	58.16	66.53
25	35	47.35	58.44	7.14	9.19	13.58	28.3	50	48.14

Analysis of critical difference for shelling efficiency (%)

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1077.7322	2	538.8661	31.56703	0.00355	6.944272
Columns	571.2480667	2	285.6240333	16.73199	0.0114	6.944272
Error	68.28213333	4	17.07053333			
Total	1717.2624	8				

CD=9.38

Analysis of critical difference for broken percentage (%)

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1136.415	2	568.2076	398.0392	2.5E-05	6.944272
Columns	93.53707	2	46.76853	32.76216	0.00331	6.944272
Error	5.710067	4	1.427517			
Total	1235.662	8				

CD=2.71

Analysis of critical difference for WKR (%)

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	3417.241622	2	1708.620811	20.9959	0.007564	6.944272
Columns	271.3256222	2	135.6628111	1.667054	0.297458	6.944272
Error	325.5151778	4	81.37879444			
Total	4014.082422	8				

CD=20.47

E_2: Analysis of different performance indicators for sprouted WMS

The analysis was done using ANOVA (two-factors without replication).

Effect of different shelling speed and m.c. on different shelling parameters for sprouted sample

Moisture content (%)	Shelling efficiency (%)			Broken percentage (%)			Whole kernel recovery (%)		
	Shelling speed (rpm)			Shelling speed (rpm)			Shelling speed (rpm)		
	1500	**1750**	**2000**	**1500**	**1750**	**2000**	**1500**	**1750**	**2000**
15	65.78	75.61	79.95	20.64	25.85	31.59	32.57	38.38	10.43
20	60.64	74.8	73.54	7.63	8.42	26.2	49.92	69.13	37.84
25	60.48	69.31	71.58	6.35	6.7	13.95	51.25	67.7	42.36

Analysis of critical difference for shelling efficiency (%)

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	67.72029	2	33.86014444	11.02722781	0.023569804	6.94427191
Columns	284.7471	2	142.3735444	46.36676937	0.001709881	6.94427191
Error	12.28238	4	3.070594444			
Total	364.7498	8				

CD=3.98

Analysis of critical difference for broken percentage (%)

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	458.3909	2	229.1954	16.80113	0.011316	6.944272
Columns	262.7789	2	131.3894	9.63148	0.029566	6.944272
Error	54.56667	4	13.64167			
Total	775.7364	8				

CD=8.38

Analysis of critical difference for broken percentage (%)

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1274.145	2	637.0723	32.29590745	0.003400755	6.94427191
Columns	1083.957	2	541.9783	27.4751877	0.004604122	6.94427191
Error	78.9044	4	19.7261			
Total	2437.006	8				

CD=10.07

E_3: Performance of the centrifugal sheller at different variables

Moisture content (%)	Shelling speed (rpm)	Initial wt. (g)	Time of shelling(min)	Wt. of unshelled seed(g)	Wt. of unshelled broken seed(g)	Wt. of whole kernel(g)	Wt. of shelled broken seed(g)	Wt. of husk(g)
Soaked WMS								
15±1	1500	50	1.35	17.45	1.98	3.47	13.00	14.11
	1750	50	1.32	9.92	2.79	2.23	15.50	19.55
	2000	50	1.00	10.49	3.45	1.79	16.37	17.90
20±1	1500	50	1.38	18.87	1.76	11.38	3.13	14.86
	1750	50	1.38	10.90	2.82	15.41	3.95	16.92
	2000	50	1.34	6.84	2.43	17.63	6.23	16.87
25±1	1500	50	1.16	30.36	2.14	7.50	1.43	8.57
	1750	50	1.15	23.85	2.47	13.25	2.12	8.30
	2000	50	1.35	17.90	2.88	12.76	3.91	12.55
Sprouted WMS								
15±1	1500	50	1.12	15.64	1.47	8.63	8.85	15.41
	1750	50	1.16	9.97	2.23	10.17	10.69	16.94
	2000	50	1.32	5.41	4.62	2.76	11.17	26.04
20±1	1500	50	1.02	18.12	1.56	13.23	2.26	14.83
	1750	50	1.12	9.82	2.78	18.32	1.43	17.65
	2000	50	1.35	10.22	3.01	10.03	10.09	16.65
25±1	1500	50	0.99	17.78	1.98	13.58	1.2	15.46
	1750	50	1.25	13.13	2.22	17.94	1.13	15.58
	2000	50	1.02	11.74	2.47	11.22	4.51	20.06
Roasted WMS								
Roasted sample (5 min)	1750	50	1.29	14.78	5.84	4.72	7.43	17.23
Roasted sample (10 min)	1750	50	1.22	8.05	4.77	3.7	14.8	18.68

Appendix F: Proximate analysis result for blended malt

F_1: Crude protein content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different proportion of sample

S_1(70:30)	S_2(60:40)	S_3(50:50)
21	25.3	25.96
20.75	24.74	27.88
21.8	23.58	26.77

Analysis of critical difference for protein

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	49.03429	2	24.5171	36.7843	0.000429	5.14325
Within Groups	3.9991	6	0.66651			
Total	53.03335	8				

CD=1.63

F_2: Fat content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different proportion of sample

S_1(70:30)	S_2(60:40)	S_3(50:50)
15.5	17.23	25.86
14.09	16.66	25.23
14	17.4	26.41

Analysis of critical difference for fat

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	210.6825	2	105.3412	261.9198	1.45E-06	5.143253
Within Groups	2.413133	6	0.402189			
Total	213.0956	8				

CD=1.26

F_3: Crude fiber content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different proportion of sample

S_1(70:30)	S_2(60:40)	S_3(50:50)
3.2	4.13	4.2
3.17	3.42	3.77
4.1	4.21	4.24

Analysis of critical difference for fiber

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.5438	2	0.2719	1.52098	0.29219	5.14325
Within Groups	1.0726	6	0.17877			
Total	1.6164	8				

CD=0.84

F_4: Ash content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different proportion of sample

S_1(70:30)	S_2(60:40)	S_3(50:50)
2	2.12	3.08
1.69	2.77	4.25
1.72	2.94	3.57

Analysis of critical difference for ash

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5.046822	2	2.523411	13.47576	0.006037	5.143253
Within Groups	1.123533	6	0.187256			
Total	6.170356	8				

CD=0.86

F_5: Carbohydrate determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different proportion of sample

S1(70:30)	S2(60:40)	S3(50:50)
58.3	51.22	41
60.3	52.41	38.87
58.38	51.87	39.01

Analysis of critical difference for carbohydrate

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	575.336	2	287.668	282.3412	1.16217E-06	5.14325
Within Groups	6.1132	6	1.01886			
Total	581.4493	8				

CD=2.01

F_6: Moisture content determination (%)

The analysis was done using ANOVA (single factor).

Replicated data for different proportion of sample

S_1(70:30)	S_2(60:40)	S_3(50:50)
6.58	7.22	6.25
6.33	6.48	5.83
5.95	6.65	6.01

Analysis of critical difference for moisture content

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.880067	2	0.440033	4.470874	0.064751	5.143253
Within Groups	0.590533	6	0.098422			
Total	1.4706	8				

CD=0.62

Appendix G: Sensory analysis result for blended malt

G_1: analysis of scores allotted for colour and flavor of each sample

The analysis was done using ANOVA (single factor).

Panelist scores for different attributes

Panel member	**Colour**				**Flavor**			
	S_1	**S_2**	**S_3**	**S_4**	**S_1**	**S_2**	**S_3**	**S_4**
1	7	8	8	9	8	9	9	9
2	8	8	8	8	7	7	7	7
3	7	7	8	8	7	8	8	9
4	8	8	8	7	7.5	7	8	8
5	6	8	7	7	7	8	8	8
6	7	7	8	8	6	8	8	7
7	7	7	8	9	6	6	8	8
8	7	8	8	9	7	8	9	9
9	8	8	9	9	8	8	9	9
10	7	7	6	8	6	6	8	4
11	6	6	7	8	7	5	7	6
12	7	7.5	8	9	4	6	9	5.5
13	8	7	7.5	8.8	8	7	7.5	8
14	8	8	9	9	8	7.5	8.5	9
15	7	8.5	8	7	7.5	8	8	7
16	6	8	6	7	6	6	8	7
17	7	8	9	9	7	8	9	9
18	7	8	7	9	8	8	8	9
19	7	8	8	8	7	7	8	9
20	8	8	7.5	8.5	6.5	8	8.5	8.5

Analysis of critical difference for colour

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12.53338	3	4.177792	7.87178	0.000122	2.724944
Within Groups	40.3355	76	0.53073			
Total	52.86888	79				

CD=O.46

Analysis of critical difference for flavor

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	18.38438	3	6.128125	5.596966	0.001601	2.724944
Within Groups	83.2125	76	1.094901			
Total	101.5969	79				

CD=0.66

G_2: Analysis of scores allotted for taste, Consistency and OA of each sample

The analysis was done using ANOVA (single factor).

Panelist scores for different attributes

Panel member	Taste				Consistency				Overall acceptability			
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	8	9	9	9	8	9	9	9	7.75	8.75	8.75	9.00
2	7	8	8	8	7	6	7	7	7.25	7.35	7.55	7.55
3	6	6	7	8	7	7	8	8	6.70	6.95	7.70	8.25
4	8	7	8	9	4	5	5	8	7.08	6.85	7.40	8.05
5	6	8	8	8	7	7	7	7	6.45	7.80	7.55	7.55
6	7	8	9	6	6	6	7	7	6.55	7.35	8.10	6.95
7	6	7	8	9	5	7	8	9	6.05	6.75	8.00	8.75
8	7	7	8	9	7	8	9	9	7.00	7.70	8.45	9.00
9	9	7	9	9	7	8	9	8	8.10	7.70	9.00	8.80
10	6.5	6	7	4	8	7	7	6	6.80	6.45	7.00	5.40
11	7	6	8	7	8	7	7	7	6.95	5.95	7.30	7.00
12	4	6.5	9	6	8	8	8	8	5.55	6.93	8.55	7.03
13	7	7.5	8	9	8	8	7	6.5	7.70	7.35	7.55	8.20
14	7	7.5	8	9	8	7	8	8	7.70	7.53	8.38	8.80
15	7.5	8	7.5	8	7	8	8	7	7.28	8.13	7.85	7.30
16	6	7	8	8	7	7	6	8	6.20	7.00	7.10	7.50
17	7	7	9	9	7	8	8	9	7.00	7.70	8.80	9.00
18	6	7	7	9	8	8.5	8	9	7.15	7.80	7.45	9.00
19	6	6.5	8	9	7	7	8.5	9	6.70	7.10	8.10	8.75
20	7	8	8.5	8.5	8	8	7.5	8.5	7.33	8.00	8.05	8.50

Analysis of critical difference for taste

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.78438	3	8.928125	8.941361	3.81E-05	2.724944
Within Groups	75.8875	76	0.99852			
Total	102.6719	79				

CD=0.63

Analysis of critical difference for consistency

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7.184375	3	2.394792	2.409454	0.073515	2.724944
Within Groups	75.5375	76	0.993914			
Total	82.721875	79				

CD=0.62

Analysis of critical difference for overall acceptability

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14.901625	3	4.967208	9.6226	1.85E-05	2.724944
Within Groups	39.231375	76	0.516202			
Total	54.133	79				

CD=0.45

G_3: Average data for sensory evaluation of blended malt by 9-point hedonic scale

Sample	**Attributes**				
	Colour	**Flavor**	**Taste**	**Appearance**	**Overall acceptability**
S1	7.15	6.93	6.75	7.10	6.96
S2	7.65	7.28	7.20	7.33	7.36
S3	7.75	8.18	8.10	7.60	7.93
S4	8.27	7.80	8.08	7.90	8.02
Weightage factor	25/100	25/100	30/100	20/100	