DEVELOPMENT OF SPROUTED SOY FORTIFIED MILLET FLOUR BASED READY-TO-EAT SNACK USING MICROWAVE PUFFING TECHNIQUE

THESIS

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Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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Enrolment Number- KK-2565 **2017**

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation in the thesis entitled **"DEVELOPMENT OF SPROUTED SOY FORTIFIED MILLET FLOUR BASED READY-TO-EAT SNACK USING MICROWAVE PUFFING TECHNIQUE"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Akola **(Pawar Savita Gangadhahrao)**

Dated: 30/06/2017 Enrolment No: KK-2565

CERTIFICATE

This is to certify that thesis entitled **"DEVELOPMENT OF SPROUTED SOY FORTIFIED MILLET FLOUR BASED READY-TO-EAT SNACK USING MICROWAVE PUFFING TECHNIQUE"** submitted in partial fulfillment of the requirement for the degree of **"Doctor of Philosophy in Agricultural Engineering (Agricultural Process Engineering)"**of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of a bonafide research work carried out by **PAWAR SAVITA GANGADHARRAO** under my guidance and supervision.

The subject of thesis has approved by the Student's advisory Committee.

Place: Akola
Date : / /2017

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Countersigned

Associate Dean,
Post Graduate Institute, Akola
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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE
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D) ABREVIATIONS

<	Less than
>	Greater than
Anon.	Anonymous
ANOVA	Analysis of variance
AOAC	Association of official Analytical Chemist
AACC	American Association of Cereal Chemist
Avg.	Average
a_w	Water activity
a_{wc}	Critical water activity
b. p.	Boiling point
BApNA	N~Benzoyl-DL-Arginine-p-Nitroanilide
BIS	Bureau of Indian Standards
C. V.	Coefficient of Variation
CCRD	Central Composite Rotatable Design
cm^2	square centimeter
CSP	Crispness, +ve peaks on force deformation curve
db	Dry basis
dm	dry matter
DMSO	Dimethyl-Sulfoxide
Dr	Doctor
e.g.	For example
EMC	Equilibrium moisture content
ER	Expansion Ratio
et. al.,	and others

etc	et cetra
exp	Exponential
Fig.	Figure
g	Gram
h	Hour
HD	Hardness, g
HDPE	High density polyethylene
HPLC	High Performance Liquid Chromatography
HTST	High Temperature Short Time
I. U.	International unit
i.e.	that is
K_2SO_4	Potassium sulphate
KCal	Kilo calorie
kg	Kilogram
kg/kg dm	Kilogram per kilogram dry matter
kPa	Kilo pascal
L	Litre
m^2	Meter square
MC	Moisture content
min	Minutes
mL	Mili Liter
MR	Moisture ratio
NaOH	Sodium Hydroxide
nm	Nano meter
OAA	Overall acceptability
^oC	Degree Celsius

P	Pressure
PDKV	Panjabrao Deshmukh Krishi Vidyapeeth
%	Percentage
ppm	Parts per million
R^2	Coefficient of determination
RH	Relative humidity
RSM	Response Surface Methodology
RTE	Ready-To-Eat
s	Second
S. N.	Serial number
S.E.	Standard Error
SD	Standard deviation
Sig.	Significant
Temp.	Temperature
U.S.	United States
v	Bulk volume before puffing, mL
V	Volt
v_0	Bulk volume after puffing, mL
viz	Namely
w/v	Weight per volume
wb	Wet basis

E) THESIS ABSTRACT

a)	Title of the thesis	:	**DEVELOPMENT OF SPROUTED SOY FORTIFIED MILLET FLOUR BASED READY-TO-EAT SNACK USING MICROWAVE PUFFING TECHNIQUE**
b)	Name of Student	:	**PAWAR SAVITA GANGADHARRAO**
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ABSTRACT

The sprouted soybean is reported to be more nutritious in terms of vitamins and amino acids and more free from anti-nutritional factors in terms of trypsin inhibition activity, and non-digestible oligosaccharides contents as

compared to that in raw or cooked soybeans. Biochemical analysis of soybean during sprouting process, showed that, the protein content increased from 38.58 to 42.25 % (db) and fat content reduced from 19.98 to 16.01 % (db). The calorific value i. e. energy of sprouted soybean was calculated to be 462.68 kcal/100 g. The main anti-nutritional factor present in soybean seed was trypsin inhibitor, which highly reduced from 4.43 to 0.205 mg/g (i.e. less than 5 per cent inhibition present in seed after sprouting plus heating at 50 ℃). As the period of germination i.e. from 0-48 h, significant and successive reduction in non-digestible oligosaccharides (raffinose family) was observed. The reduction of about 88 % of non-digestible oligosaccharides (Raffinose family) after 48 h rinsing of soybean was observed. Therefore, these sprouted soybeans are useful for consumption.

Extrusion cooking is a HTST cooking process, which could be used for processing of starchy as well as proteinaceous materials. The composite flour was taken in the ratio of Finger millet: Foxtail millet: Peral Millet: Barnyard millet: 40:30:20:10 respectively and two gram of salt per 100 gram of flour was added for taste. The composite flour was mixed together with addition of 55 mL water for cold extrusion. These cold extrudates were steamed for 15 min at 1 kg/cm^2 in kitchen pressure cooker. The prepared mixture of basic ingredients was kneaded for 10 min to obtain granular mixture by using Dolly Mini P3 Pasta Machine. The optimal conditions of composite millet flour based cold extruded could be conducted by convective heating temperature at 196 ℃ for 132 s followed by microwave power of 520 W heating for 173 s. The microwave puffed product at the optimal process condition was having average moisture content of 0.032 kg/kg dm, crispness of 15.13 (+ve peaks), expansion ratio of 1.96 and colour (L-value) found to be 43.97.

The fresh cold extrudate was prepared from composite millet flour at moisture content of 0.6024 kg/kg dm, adding sprouted soy paste at various levels upto 20 per cent. The optimal level of incorporation of sprouted soybean fortification was found to be 20 g dm of sprouted soy per 100 g dm of composite flour during preparation of RTE snack foods.

Biochemical analysis optimally developed sprouted soy-fortified composite millet flour based RTE snack food was found showed that the final product was having protein content 15.82 percent, with very less amount of fat

content 1.13 per cent db and high amount of ash content 4.34 per cent db i.e. minerals. No trypsin inhibitor activity was detected after microwave puffing of sprouted soy fortified composite millet flour based RTE snack food. Besides, non-digestible oligosaccharide's (NDO's) like raffinose family found to be reduced by 88 per cent.

The microwave puffed sprouted soy fortified composite millet flour based RTE snack food could be stored in MP (40 microns) package at moderate RH (65 per cent) and ambient temp of 30 ℃ for considerably long shelf life for 5 months.

CHAPTER I

INTRODUCTION

The importance of breakfast cereal is gaining significance in an era of changing life-style, rapid urbanization, convenience and above all, a health-conscious society. The convenience foods as ready-to-eat (RTE) foods are also becoming popular among the people. Convenience foods as defined by Franzese (1981) are “those that are ready-to-serve in that the manufacture has added services to the basic ingredients to eliminate all the requirements for preparation activities onsite, except when appropriate reheating and seasoning to taste”. However, the balanced and sufficient nutrition content of available ready-to-eat foods is a major issue of verification.

Millets play a major role in the food security and economy of many under developed countries in the world. They are commonly cultivated in India, Africa and China. Millet is thought to be one of the first grains cultivated by man. The first recorded reports on the cultivation of millet dates back to about 5,500 BC in China (Crawford, 2006). They are extremely important crops in semi-arid regions where other crops normally do not survive. Millets ranks as the sixth most important cereal and feeds one third of the total world population (Saleh et al., 2013). Another attribute of millets that make them a preferred choice in areas where they are cultivated, are their short harvest period (45-65 days) (Bukhari et al., 2011).

Millet is a generic term used for the grains from the heterogeneous group of forage grasses. They are small sized grains and are grouped along with maize and sorghum as 'coarse cereals' perhaps because of their typical grain texture, which makes them difficult to process as well as cook in convenience form similar to rice and wheat. They assume significance for food and nutritional security in most of the Asian and African countries because of their hard nature and ability to grow in rain-fed lands with very little agricultural inputs as compared to most of the cereals. The annual production of the millets worldwide is about 32 million tonnes, of which a little more than half the quantity is produced in India. Indian food grain production in 2012-

13 has been over 255.36 million tons, out of which millets has been 17.67 million tons and soybean 18.45 million tons. India is the top consumer and producer of millet in the world and Indian eat 42 per cent of millets produced globally (Anonymous, 2013).

Bajra or pearl millet, ragi or finger millet, navane or foxtail millet, samai or little millet, haraka or kodo millet, panivaragu or proso millet, banti or barnyard millet are the important millets cultivated largely in the Asian and African countries. These are cultivated in India in almost all the states and the major millet producing states are Karnataka, Rajasthan, Gujarat, Haryana and Maharashtra.

Growing traditional local landraces and under ecological conditions, most millets such as foxtail are totally pest free. They need very little water for their production. They do not demand chemical fertilizers. In fact, under dry land conditions, they grow better in the absence of chemical fertilizers. And hence do not need any pesticides. Even in storage conditions, most millet such as foxtail not only need any fumigants but act as anti pest agents to store delicate pulses such as green gram. Each of the millets is a storehouse of dozens of nutrients in large quantities. They include major and micro nutrients needed by the human body. Hence, they can help people withstand malnutrition (Anonymous, 2015a). As food, they are nutritionally equivalent or superior to most cereals; containing high levels of methionine, cystine, and other vital amino acids for human health. They are also unique sources of pro-vitamin A (yellow pearl millets) and micronutrients (Zn, Fe and Cu) which are especially high in finger millet (Olibana, 2003).

Millet grains are now receiving specific attention from these developing countries in terms of utilization as food as well as from some developed countries in terms of its good potential in the manufacturing of bioethanol and biofilms (Li et al., 2008). Millets also offer several health benefits to consumers. These crops lack gluten and hence can be consumed by people suffering from celiac disease (Gabrovska et al., 2002). Millet consumption can also lower glycemic response, which can be helpful for the treatment of type II diabetes (Choi et al., 2005). Inclusion of millet in the human diet can also

lower the risk of duodenal ulcers, anemia and constipation (Jayaraj et al., 1980, Nambiar et al., 2011). For patients suffering from allergic diseases such as atopic dermatitis, Japanese barnyard millet grains have been recommended to replace rice and wheat grains (Watanabe, 1999). Dietary fibre content in pearl and finger millet was found to be higher than that in sorghum, wheat and rice (Kamath and Belavady, 1980). Millets are also rich in phenolic acid and has high anti-oxidant activity (Chandrashekhar and Shahidi, 2010). They are valuable sources of some essential minerals such as potassium, magnesium, calcium, iron and zinc (Ravindran, 1991). Despite their beneficial nutritional properties and tolerance for adverse growing conditions, millet consumption has been less compared to major cereals such as rice, wheat and corn. Millet products from 100 per cent millet flour are rarely manufactured. Among millets, small millets have been most neglected. There is a need to increase awareness about the superior nutritional quality of millets and make them one of the important commodities in our food basket.

Therefore, the incorporation of minor millets like barnyard, foxtail, finger, pearl, proso, etc. are along with cereals like sorghum, wheat, oats, rice, maize, etc. could be even better way for nutritious foods. Millets are most recognized nutritionally for being a good source of minerals i.e. calcium, magnesium, manganese and phosphorus. Research has linked magnesium to a reduced risk for heart attack and phosphorus is important for the development of body tissue and energy metabolism. Millets are also rich in phytochemicals, including phytic acid (Shashi et al., 2007), which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk. Thus, millets are strategic in terms of their food, nutritional and livelihood security and their role in local agro-ecosystems (Joshi et al., 2008). The finger millet contains important amino acids viz., isoleucine (4.4 g), leucine (9.5 g), methionine (3.1 g) and phenyl alanine (5.2 g) which are deficient in other starchy meals. Millets also contains B vitamins, especially niacin, Pyridoxine and folic acid (Vachanth et al., 2010). The Indian Council of Medical Research recommended levels of 520 g cereals, 50 g pulses and 45 g oil/fat along with other necessary components for balanced diet for adult (Singh, 2000). The present per capita cereal availability (530 g/head per day) is sufficed whereas

the pulses availability (35 g/head per day) is below the minimum recommendation thus making the diet of proteins.

Soybean (*Glycine max* L.) described as “golden bean” has ensured its widespread consumption by strong evidence of low incident rate of breast, colon and prostate cancer or coronary diseases in the eastern countries (Plaza et al., 2003). It contains 38-42 per cent high quality vegetable protein and is rich in sulphur containing amino acids, which make soy protein as most satisfying pulse proteins as per FAO pattern (Manay and Shadaksharaswamy, 2004). It is rich in minerals (calcium, phosphorus and iron) and vitamins.

In general, increase in human consumption of soy products consumption has limited due to trypsin inhibitor, saponin contents and unavailable sugars like non-digestible oligosaccharide’s (NDO’s, i.e. α - galactose such as raffinose, stachyose and verbiscose) in soybean (Prasad et al., 2001). The sprouted soybean is reported to be more nutritious in terms of vitamins and amino acids and more anti-nutrition free in terms of trypsin inhibition activity, saponin and non-digestible oligosaccharides contents as compared to that in raw or cooked soybeans. The sprouting followed by cooking of soybeans ensures more 60 % reduction in flatulence effect in human intestine (Ali et al., 1988). Sprouted soybean prevent the diseases like cancer, lowering the level of blood cholesterol and reducing the risk of coronary heart disease, modulating the immune response and stimulating the mineral absorption (Wang et al., 2007). It also works as an antihypertensive and anti-diabetic agent and prevents the diseases like hypertension and diabetes (MaCue et al., 2005). Better and safe utilization of soybean may project it as pulse grain for protein and helpful in combating the protein deficiency.

The different technologies like baking, roasting, extrusion cooking, puffing as sand/ salt puffing, oil frying, hot air puffing, gun puffing, microwave puffing etc. are being utilized to prepare a variety of ready-to-eat foods. The baking and roasting are high temperature long time processes whereas extrusion cooking is high temperature high pressure technique and involves use of expensive and sophisticated technology. The puffing technology

imparts the complete processing at high temperature and in short time but utilizes only whole grains like rice, paddy, sorghum, maize, wheat, bajra, etc. i.e., single source of nutrition for preparation of RTE foods. The sand/salt puffing processes are likely to contaminate the end product. The gun puffing and hot air puffing require huge heating arrangements. The microwave puffed product is fat free.

Extrusion cooking is one of the very popular contemporary food processing technologies and is largely followed for corn and rice but the millets could also be extruded to prepare RTE products. A majority of world population suffers from qualitative and quantitative insufficiency of dietary protein and calories intake. In all such cases, physiological maintenance and growth are impaired and malnutrition results. In this context, extrusion is a beneficial process. Extrusion cooking is a HTST cooking process, which could be used for processing of starchy as well as proteinaceous materials. The use of extrusion cooking has distinct advantages like versatility, high productivity, high product quality, increase in in-vitro protein digestibility (Dahlin and Lorenz, 1992) and production of new food without effluents. Extrusion Cooking is accomplished through the application of heat either directly by steam injection or indirectly through jacket or by dissipation of mechanical energy through shearing occurring within the blend. Since, the seed coat or the bran affects the expansion ratio and also the eating quality of the extrudates, it is desirable to use refined grits and flour, preferably of less than 40 mesh size. Equilibrating the flour to about 18 per cent moisture content and extruding in a single or twin-screw extruder at about 150 ℃ and 200 rpm, gives extrudates of highly desirable food qualities with an expansion of 1.5-2 times. The products will have crunchy texture and can be coated with traditional ingredients to prepare sweet or savoury snacks. Alternately, the grits could be mixed with spices and condiments prior to extrusion to obtain RTE snacks of desirable taste.

Therefore, the way to prepare composite dough from minor millet grains and fortifying the same with sprouted soybeans is thought to be taken up for preparing RTE foods by following microwave puffing technique. This will help prepare the nutritionally reach RTE foods with available domestic

equipment like microwave oven. Keeping in view the aforesaid discussion, the present study has been undertaken with the following specific objectives:

1. Study on biochemical profile of soybean during process of sprouting.
2. Optimization of microwave puffing process for preparing ready-to-eat snack from millet flours.
3. Optimization the fortification level for incorporation of sprouted soybean in millet flour for preparing microwave puffed ready-to-eat snack.
4. Study on mass transfer during microwave puffing process of sprouted soy fortified composite flour based ready-to-eat snack.
5. Study on biochemical analysis of optimally developed ready-to–eat snack during process.
6. Study on shelf life of optimally developed ready-to-eat snack.

Hypothesis

The demand of ready-to-eat foods are increasing day by day. The balanced and sufficient nutrition content of available ready-to-eat foods is a major issue.

Soybean is rich in vegetative protein but its consumptions is limited due to antinutritional factors present in soybean which are harmful for digestive system. If the appropriate process will be used to remove these antinutritional factor, which helpful to increase in soybean consumption.

Now, the minor millets are store house of vitamins and minerals. But these are less popularised due to unawareness among the peoples.

Therefore, ready-to-eat snack will be developed by the fortification of these millets and appropriately processed (sprouted) soybean not only increase the nutritional value also increase the consumption of minor millets.

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with the review of literary information required to formulate the research problem, carry out the work and to discuss the findings. The work, relevant to the development of RTE snack foods, carried out by various investigators was reviewed extensively. The specific information on availability, importance and preparation of basic ingredients, importance of snacks foods, various types of puffing processes and the necessity of steaming before puffing of RTE snack foods are presented and discussed in brief. Review on different quality parameters associated with the development of snack food, mass transfer kinetics and estimation of chemical composition during process, changes occurring during their storage has been presented. Response surface methodology used by various researchers during the development of different snack foods has also been reported in the following paragraphs.

2.1 Composite flours

Minor millets like pearl millet, finger millet, foxtail millet and barnyard millet are used as base composite flour for the preparation of ready-to-eat snack foods.

The composite flour technology refers to the process of mixing of two or more types of grains to make use of local raw material to produce high quality food products in an economical way. Cereal-pulse combinations have been employed for the production of various products. In addition to being rich source of protein, pulses are being recognized as having therapeutic/ medicinal properties (Shahzadi et al., 2005). Cereal grains and legumes play significant role in supplying the nutrients, as well as providing over 70 % of the daily energy requirements (Edwards et al., 1971). Fortification of finger millet in chapattis not only improves the taste but also helpful in controlling glucose levels in diabetic patients very efficiently (Kang et al., 2008). The bulkiness of the fiber and the slower digestion rate makes us feel fuller on, fewer calories and therefore may help to prevent from eating excess calories. Its high fiber

content is further helpful to the individuals having the problem of constipation (Cade et al., 2007).

Multi-grain flour by combining wheat and finger millet in the ratio of 7:3 is one of the simple semi-finished products suitable for making chapatti (roti). Kamaraddi and Shanthakumar (2003) incorporated a small millet flours to commercial wheat flour and studied the effect of incorporation of refined millet flours on chemical, rheological and baking characteristics. It was found that substitution of wheat flour with millet flours was possible from 10 to 20 % level. Barnyard millet and proso millet can be added upto 20 and 15 %, respectively.

Singh et al. (2005) prepared composite flours of foxtail, barnyard and finger millet with wheat flour by adding 10-30 % millet flour and observed that addition of milled millet flour to wheat flour increased the concentration of protein, fat and ash but decreased the carbohydrates. Addition of milled barnyard millet flour increased significantly ($p<0.01$) the level of protein, crude fat and total ash contents but whole barnyard flour decreased significantly ($p<0.01$) the level of protein. With the increase in the level of finger millet flour in the blend, protein content decreased from 11.59 to 10.99 % whereas fat and ash contents increased from 1.06 to 1.37 and 0.55 to 1.37 %, respectively with non-significant variation in carbohydrate content.

Devaraju et al. (2008) prepared pasta using 50 % of finger millet flour (FMF), 40 % refined flour (RWF) and 10 % defatted soy flour (DSF). The protein content of pasta products formulated from finger millet composite flour, ranged from 14.48 to 17.78 % as compared with 13.12 % in the controlled pasta.

Organically produced composite flours made from basic flours of wheat (refined) or spelt (refined, wholegrain) and amaranth flour in the proportions of 10 %, 20 %, and 30 % (flour basis) were compared to cereal flours. The amaranth addition strengthened the dough, mainly by decreasing its extensibility and in spelt containing composite flours, also by increasing the resistance to extension. Considering the results obtained and the characteristics of the basic flour used, the amaranth substitution of 10–20 %

evidently improves some rheological properties and strengthens the dough (Grobelnik et al., 2009).

The incorporation of millet flour blend was also found to improve the quality of composite flour containing kodo and barnyard millet flour, whole wheat flour and defatted soy flour in terms of increasing nutrient density, thinner gruel by lowered viscosity, and an increase in the level of synergetic that may improve the resistant starch content on storage (Vijayakumar and Mohankumar, 2009).

Anuradha et al. (2010) observed that the cake sample prepared with combination of refined wheat flour and malted *Ragi* flour was rich in calcium, iron, phosphorous, and crude fibre. The cake prepared with 60 % and 70 % malted *Ragi* flour had highest mineral and fibre content than other samples, but the sensory score for the same were low due to the loss in sponginess and increased intensity of brown colour. The cake sample prepared with 50 % malted *Ragi* flour had sensory score same as the control. Hence, the cake sample prepared by supplementation with malted *Ragi* flour would be beneficial for growing children, pregnant women, lactating women and anemic patient.

Deshpande and Poshadri (2011) focused on the use of foxtail millet along with other flour for production of ready-to-eat snack products using extrusion cooking. Composite flours were prepared using whole Foxtail millet flour and other flours namely; rice flour, chick pea, Amaranth seed flour and cow pea. Nutritional properties of the blends were analysed and extrusion cooking was carried out using a twin-screw extruder at optimized extrusion parameters namely temperature: 115 ℃ and 90 ℃ for two different heating zones, die diameter: 3 mm and screw speed: 400 rpm. The extrudate physical properties namely bulk density, piece density, expansion ratio and moisture retention were also analysed. The organoleptic qualities of extruded samples were analysed by panel lists on a 9-point hedonic scale. The results indicated that composite flour (foxtail millet: amaranth; rice; bengal gram; cow pea in the ratios of 60:05:05: 20:10) could be used to produce quality extrudates with acceptable sensory properties.

In order to develop finger-millet-incorporated noodles for diabetic patients, FMF was blended in various proportions (30 to 50 %) into refined wheat flour and used for the preparation of noodles. Based on the basis of sensory evaluation, the 30 % finger-millet-incorporated noodles were selected and evaluated for glycemic response compared to a control. The results indicated that glycemic index of 30 % finger-millet-incorporated noodles was significantly lower than control noodles (Shukla and Srivastava, 2011).

Furthermore, whole pearl millet, finger millet, and decorticated soybean-blended (millet plus soy) extrudate formulations were designed using a linear programming (LP) model to minimize the total cost of the finished product. LP-formulated composite flour was extruded through a twin-screw food extruder at different extrusion conditions. It was found that the pearl-millet-based blend expanded snacks showed promising features for the production of low-cost extrudates (Balasubramanian et al., 2011).

For the preparation of breads, millet-based composite flours were optimized. Barnyard millet plus wheat composite flour was formulated and prepared by mixing 61.8 g/100 g barnyard millet, 31.4 g/100 g wheat, and 6.8 g/100 g gluten. The results of sensory analysis showed that the acceptability of bread samples prepared from composite flours was almost equal to that of the wheat bread (Singh and Raghuvanshi, 2012).

The suitability of oat, millet and sorghum in bread making was assessed in simple binary wheat flour matrices in which wheat flour was replaced from 0 % to 60 %. The results indicated that oat, millet, and sorghum represent a viable alternative to make aerated breads with mitigated technological and sensory constraints based on non-viscoelastic cereals (Angioloni and Collar, 2012).

The composite flour with the proportion of rice flour 30 %, cassava flour 40 %, potato starch 15 %, soybean flour 14.5 % and xanthan gum 0.5 % had the physicochemical, functional and pasting properties that comparable to those of wheat flour (Tharise et al., 2014).

2.2 Nutritional profile of millets

By any nutritional parameter, millets are far ahead of rice and wheat in terms of their mineral content, compared to rice and wheat. It has been reported that millets are rich source of nutrients and contain 60-70 % dietary carbohydrates, 6–19 % protein, 1.5-5 % fat, 12-20 % dietary fibre, 2-4 % minerals, and several other phytochemicals (Haldimani and Maldeshi, 1995). Millet is a starchy food with a 25:75 amylose to amylopectin ratio and is a fairly good source of lipids (3-6 %), having about 50 % of the lipids in the form of polyunsaturated fatty acids (Sridhar and Lakshminarayana, 1994).

Although millet is known to contain amylase inhibitors, the carbohydrate digestibility of millet foods is not affected because of heat-labile nature of the inhibitors (Chandrashekher et al., 1981). The free sugars found in millet are glucose, fructose, sucrose and raffinose and their contents ranges from 1-1.4 % with sucrose (0.3-1.2 %) being the predominant sugar (Malleshi et al., 1986). Total sugars in small millets ranged from 1.4-2 % with Proso having highest contents. Millets have total starch ranging from 64-79 % (Geervani and Eggum, 1989). Amylose contents in millets ranges from 26-30 % and amylopectin 69-74 % (Kumari and Thayumanavan, 1998).

Among the millets, pearl millet has the highest content of macronutrients and micronutrients such as Iron, zinc, Magnesium, Phosphorous, Folic acid and Riboflavin. Finger millet is an extraordinary source of calcium. Though low in fat content, it is high in PUFA (polyunsaturated fatty acids) (Antony et al*.,* 1996). It is also rich in essential amino acids, like lysine, threonine, valine, sulphur containing amino acids and the ratio of leucine to isoleucine is about 2 (Ravindran, 1992; Antony et al*.,* 1996; Indira and Naik, 1971). The chemical score (percentage of the most limiting amino acid compared to a standard protein like egg protein) of finger millet is about 50 which is relatively better than other millets, sorghum and pearl millet (43) (FAO, 1970; Eggum et al*.,* 1982). Foxtail millets have high antioxidant activity and barnyard millets are rich in iron. In this fashion, nutrient to nutrient, every single millet is extraordinarily superior to rice and wheat and therefore is the solution for the malnutrition that affects a vast

majority of the Indian population (Anonymous, 2015a). Following tables shows the comparison of nutritional profile of millets with big cereals.

Table 2.1: Dry matter profile of Millets

Millets	Energy (kcal)	Carbohydrate (g)	Protein (g)	Fat (g)	Fiber (g)
Pearl	363	67	11.8	4.8	**20.4**
Foxtail	351	63.2	11.2	4	**17.62**
Finger	336	72.6	7.7	1.5	**18.8**
Barnyard	300	55	11	3.9	**13.7**
Wheat	348	71	11.6	2.00	12.9
Rice	362	76	7.9	2.70	5.2
Sorghum	329	70.7	10.4	3.10	14.2

(Source: Anonymous, 2015b)

Table 2.2: Vitamin Profile of Millets (mg/100g)

Millets	Vit. A	Vit. B Complex				Vit. E
		Thiamin	Riboflavin	Niacin	Folic acid	
Pearl	**132**	0.41	**0.28**	**4.5**	**45.5**	19.0
Foxtail	32	**0.59**	0.11	3.2	15.0	9.3
Finger	42	0.42	0.19	1.1	18.3	**22.0**
Barnyard	--	0.33	0.10	4.2	--	--
Wheat	64	0.410	0.100	5.10	36.6	--

(Source: Anonymous, 2015b)

Table 2.3A: Micronutrient Profile of Major nutrients (mg/100g) of Millets

Millets	Calcium	Phosphorus	Manganese	Potash	Sulfur	Iron	Sodium	Chlorine
Pearl	42	269	**137**	307	147	2.9	10.9	39
Foxtail	31	**290**	81	250	**171**	2.8	4.6	37
Finger	**350**	283	**137**	**408**	160	3.9	**11.0**	**44**
Barnyard	22	280	8.2	--		**18.6**		
Wheat	--	306	138	284	128	3.5	17.1	47
Rice	--	160	90	--		1.8	--	--
Sorghum	25	222	171	131	54	5.4	7.3	44

(Source: Anonymous, 2015b)

Table 2.3B: Micronutrient Profile of Trace Elements (mg/100g) of millets

Millets	Cupper	Manganese	Molybdian	Zinc	Chromium
Pearl	1.06	1.15	0.069	**3.1**	0.023
Foxtail	**1.40**	0.60	0.070	2.4	**0.030**
Finger	0.47	**5.49**	**0.102**	2.3	0.028
Barnyard	0.60	0.96		3	0.09
Wheat	0.68	2.29	0.051	2.7	0.012
Rice	0.14	0.59	0.058	1.4	0.004
Sorghum	0.46	0.78	0.039	1.6	0.008

(Source: Anonymous, 2015b)

Table 2.4. Essential Amino Acid Profile of Millets (mg/g of N)

Millets	Histidine	Lysine	Tryptophan	Phenyl	Tyrosine	Methionine	Threonine	Leucine	Isoleucin
Pearl	**140**	190	**110**	290	200	150	140	750	260
Foxtail	130	140	60	**420**	--	180	190	**1040**	**480**
Finger	130	**220**	100	310	**220**	**210**	**240**	690	400
Barnyard	12	15	0.5	43	--	18	200	650	360
Wheat	130	170	70	280	180	90	180	410	220
Rice	130	230	80	280	290	150	230	500	300
Sorghum	160	150	70	300	180	100	210	880	270

(Source: Anonymous, 2015b)

Table 2.5: Fatty Acid Composition of Millets

Millets	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Pearl	**20.85**		**25.40**	46.0	**4.10**
Foxtail	6.40	**6.30**	13.0	**66.50**	--
Wheat	24.5	1	11.5	56.3	1.1
Rice	15	1.9	42.5	39.1	2.7
Sorghum	14	2.1	31	49	--

(Source: Anonymous, 2015b)

2.3 Health benefits of minor millets

Millets are a rich source of phosphorus which is an important mineral for energy production and is an essential component of ATP-the energy store of the body. It also forms an essential part of nervous system and cell

membranes. The energy of millet is greater than sorghum and nearly equal to that of brown rice because the lipid content is generally higher (3 to 6 %). Magnesium from millets also helps to relax blood vessels, enhances nutrient delivery by improving the blood flow and maintains the blood pressure and thus further protects the cardiovascular system. Magnesium increases insulin sensitivity and lowers triglycerides. It also acts as a co-factor for more than 300 enzymes (Anonymous, 2015a).

Use of minor millet lowers the risk of diabetes. Millets helps to lower blood glucose levels and improves insulin response. Besides, the magnesium present in millets is a co-factor in various enzymes involved in the secretion of insulin and metabolism of glucose in the body. Whole grains improve insulin sensitivity by lowering glycemic index of the diet by increasing content of fibre, magnesium and vitamin-E (Anonymous, 2015a).

Suman et al., (1992) assessed the nutritional quality of Japanese barnyard millet (JBN), its protein content, quality and digestibility and found that the proximate composition of the millet resembles that of other millets/cereals. The protein content had a mean value of 36.7 g/kg and glutelin's were the major storage proteins (60.8 %) whereas phenolics and tannins were found to be low.

Phenolic compound especially flavonoids, have been found to inhibit tumor development (Huang and Ferraro, 1992). Sharma and Kapoor (1996) have reported the phenols in pearl millet grains as 608.1 mg/ 100 g and that in pearl millet flour as 761 mg/100 g. Pearl millet can be recommended in the treatment of celiac diseases, constipation and several non-communicable diseases (Nambair et al., 2011).

Mani et al. (1993) have reported that pearl millet has the lowest GI (55) as compared to Varagu alone and in combination with whole and dehusked green gram, Jowar and Ragi. Foods with a low glycemic index are useful to manage maturity onset diabetes, by improving metabolic control of blood pressure and plasma low density lipo-protein cholesterol levels due to less pronounced insulin response (Asp, 1996).

Pearl millet is a gluten free grain and is the only grain that retains its alkaline properties after being cooked which is ideal for people with wheat allergies. Pearl millet grains are all very high in calories precisely the reason they do wonders for growing children and pregnant women (Anonymous, 2015a).

Nutraceuticals are health enhancing physiologically active food components which are also called as phytochemicals. They play a key role as health protective and disease preventive agents and have tremendous impact on the health care system. There has been an upsurge of interest among scientific community to characterize the role of nutraceuticals in management of diseases and development of functional/designer foods for various purposes. Alongside, elevated interest among health-conscious consumers in health foods is also evident in the community. Millets have a role to play here, owing to their nutrient and phytochemical composition (Ugare, 2008).

Shashi et al. (2007) reported that ragi is an important cereal because of its storage properties of the grains and the nutritive value, which is higher than that of rice and equal to that of wheat. It is also a good source of micronutrients like Calcium, Iron, Phosphorous. Due to presence of anti-nutrients in grains such as tannins and phytates, these micronutrients are less bio-accessible. These anti-nutritional factors modify the nutritional value of the individual grains. Among millets, finger millet was reported to contain high amounts of tannins (Ramachandra et al., 1977), ranging from 0.04 to 3.47 %. Poor iron availability in brown varieties is due to their high tannin content which adversely affect the nutritional quality of the grains (Udayasekhara and Deosthale, 1988).

Kang et al. (2008) observed that the ragi provides higher level of calcium, antioxidants properties, phytochemicals, which makes it easily and slowly digestible. Hence it helps to control blood glucose levels in diabetic patients very efficiently.

Lakshmi and Sumathi (2002) reported that the bulkiness of fibers and the slower digestion rate makes us feel fuller on, fewer calories and therefore may help to prevent us from eating excess calories. Therefore, ragi is

considered to be ideal food for diabetic individuals due to its low sugar content and slow release of glucose/sugar in the body.

Highest phenolic content is reported for kodo (368 mg/g) followed by finger (brown variety), little, foxtail and barnyard millet (Hegde and Chandra, 2005). Phenolic acids in finger millet are present mostly in free form. Ferulic and p-coumaric acid are the major bound phenolic acid (19 mg/100 g) identified, whereas protocatechuic acid is reported as the major free phenolic acid (45 mg/100 g) in finger millet. The antioxidant activity of a free phenolic acid mixture of finger millet is higher compared to that of a bound phenolic acid mixture (Rao and Muralikrishna, 2004).

2.4 Protein fortification

Fortification is the nutritional improvement of food by the addition of nutrients such as vitamins, minerals and amino acids (or other protein supplements). Protein malnutrition is a serious problem in India due to cereal based dietary pattern. Therefore, various preparations based on cereal-pulse combination are of paramount importance to improve the protein quality of Indian diet. Although, pulses are good sources of plant protein, their availability is progressively decreasing due to stagnation in production and increase in population (Swaminathan, 1985). Soybean is a versatile plant food that provides high quality protein but only minimal saturated fat. Hundred grams of soybean contains 8.1 g of moisture, 43.2 g of protein, 19.5 g of fat, 20.9 g of carbohydrates, 240 mg of calcium, 10.4 mg of iron and 690 mg of phosphorus (Gopalan et al., 1999).

However, recent excitement has focused on soy foods as a rich and essentially unique dietary source of isoflavones and phytoestrogens. Soy protein also directly lowers serum cholesterol levels (Messina, 1997). Soy food given to children daily improves mental and physical abilities, memory power and haemoglobin levels reported by ASA. Soybean was shown to be extremely rich in nearly all the essential amino acids needed by man (Cook and Briggs, 1977).

Jansen et al. (1978) evaluated the nutritional quality of extrusion-cooked corn-soy blends and found these to be comparable to that of casein.

Dublish et al. (1988) studied the nutritional quality of extruded rice, ragi and defatted soy flour blends. The mean protein efficiency ratio (PER) values of extruded products were found to be significantly higher than those of unprocessed blends. They concluded that improved palatability of the extruded products was responsible for this change.

Pracha and Chulalak (2000) has developed a nutritious soy fortified snack with good texture and good protein quality containing 18 % of soy flour (9 % DFS + 9 % FFS) replaced in a blends of corn grit and broken rice, 2 % soybean oil and fortified with a mixture of vitamins, minerals and amino acids and it could be regarded as a palatable and nutritious snack.

Saimanohar et al. (2005) prepared a high protein nutritional baked snack food comprising vegetable sources as wheat flour, roasted peanut paste, sesame seed, soybean flour and well balance mixture of vitamins, minerals and others.

Awasthi et al. (2012) developed a soy fortified high protein and high calorie supplementary biscuits. The treatment was found to be the best with addition of highest percentage of soybean (20 %).

2.5 Sprouting of soybean

Bates and Mathews (1975) have studied the ascorbic acid and *β-carotene* in soybeans as influenced by maturity, sprouting, processing, and storage. Soybeans harvested at various stages of maturity and sprouted were evaluated for ascorbic acid and *β- carotene* in the fresh, cooked, canned, frozen and stored packs. Both vitamins decreased markedly as beans matured and increased upon sprouting. Ascorbic acid (mg/100 g) was found to be as in fresh-30, dry-2, sprouted-11), β-carotene (mg/100 g) as in fresh-0.35, dry-0.12, sprouted-0.20. Severe ascorbic acid losses (50 to 70 %) were experienced due to cooking or canning, whereas freezing and storage losses were less (10-30 %). *β-carotene* retention was 80-90 % in all treatments.

Senratna and McKersie (1983) have studied the dehydration injury in germinating soybean seeds. The sensitivity of soybean seeds to dehydration changed during germination. Seeds were tolerant to dehydration up to 10 % moisture if dried at 6h of imbibition. Dehydration injury appeared as loss of

germination, slower growth rates of isolated axes, hypocotyls and root curling, and altered membrane permeability. Increased electrolyte leakage due to dehydration treatment was observed only from isolated axes but not from cotyledons, suggesting that cotyledons are more tolerant of dehydration. The transition from a dehydration-tolerant to a dehydration-susceptible state coincides with radical elongation. However, the prevention of cell elongation by osmotic treatment in polyethylene glycol or imbibition in 20 µg/mL *cyclohexamide* did not prevent the loss of dehydration tolerance suggesting that neither cell elongation nor *cytoplasmic* protein synthesis was responsible for the change in sensitivity of soybean seeds to dehydration. Furthermore, the rate of dehydration or rate of rehydration did not alter response to the dehydration stress.

Ali et al. (1988) studied the comparative flatus (volume, mL of gas present in the gastro intestinal tract after 4-6 h) production with raw/cooked and germinated pulses. Study was undertaken with seven samples like black soybean, bengal gram, black gram, pigeon pea, green gram, cowpea and horse gram for eight rats per group of 4-6 h feeding. The raw samples contained 4.21, 4.60, 4.18, 3.73, 1.27, 3.40 and 2.13, respectively. The cooked samples contained 5.20, 5.18, 4.76, 3.81, 2.26, 4.03 and 2.66 which seem to be increased than that of raw samples and also in germinated samples the values were decreased half of the cooked samples such as 2.14, 2.35, 2.40, 1.63, 0.62, 1.93 and 0.83 respectively. Germinated and cooked samples were contained nearly nil level of flatus production in bengal gram, black gram, cowpea and horse-gram and in other samples reduced up to 1.67, 1.51 and 0.50 for black soybean, pigeon pea and green gram respectively.

Verma and Mehta (1988) studied the physical characteristics, sensory evaluation and the effect of sprouting, cooking and dehulling on the antinutritional factors of rice bean. The study of physical characteristics showed that rice bean having more length and weight and more edible portion as compared to mung bean. Sensory evaluation of cooked rice bean with and without sprouting was rated at par with cooked mung bean. Pressure cooking of rice bean at 6.8 kg for 20 min was more effective and time saving than

open pan cooking. The effect of sprouting, cooking and dehulling on antinutritional factors revealed that on sprouting, the phytic phosphorus values for rice bean as well as mung bean decreased by 11.3 and 9.8 %, respectively as compared to those of the whole un-germinated beans. The trypsin inhibitor activity of rice bean was decreased by 44 % on cooking and 30 % on sprouting. The hemagglutinating activity in raw rice bean was 80 and steamed, sprouted and dehulled samples showed no residual hemagglutinating activity. Sprouting reduced the tannins in rice bean by 30.8 % which were further reduced by 55 % when sprouted rice bean was dehulled.

Nsofor and Osuji (1997) studied the stability, rheology and chemical properties of soymilk concentrates developed from sprouted soybeans. Sterilized (121 ℃, 10 min) soymilk concentrates (20 and 30 % solids) were prepared from blanched and un-blanched sprouted soybean and their storage stability, rheological behaviour and chemical properties were evaluated. Concentrate from blanched-sprouted soybean were stable (uncoagulated) for 9 months in ambient tropical storage (26-32 ℃), while those from un-blanched sprouted soybeans (control) coagulated within one-month storage.

Dhaliwal and Aggarwal (1999) have studied the composition of soybeans as affected by duration of germination and drying temperature. Soybeans were soaked in water for 6h, followed by germination for 36h and 48h at 35 ℃. After requisite germination, the germinated samples were divided into two lots. One lot was dried at low temperature (30 ℃) and other at higher temperature (70 ℃) in tray driers. The germinated and dried samples were dehulled and milled to flour. The fat content of soybeans decreased with increase in germination time. Free fatty acid content also decreased with increase in germination time. Oleic acid level first decreased with 36h germination and thereafter, an increase was noticed after 48h of germination. Similar results were recorded for linolenic acid content in germinated soybeans dried at low temperatures.

Ahmad and Pathak (2000) have studied the nutritional changes in soybean during germination. Soybean seed was allowed to germinate under two sets of temperature (22 and 25 ℃). The germinated seed from both the

sets were dried up to 10 % moisture level. The dried seeds were pulverized and analysed for determination of nutritional parameters along with control soybean samples for comparison. The result showed that the germination increased ascorbic acid and riboflavin contents drastically in comparison to control samples. Considerable changes in thiamine were also observed after germination.

MaCue et al. (2005) studied an anti-diabetic and anti-hypertensive potential of sprouted and solid-state bio-processed soybean. The result suggest that sprouting and dietary fungal bio-processing of soybean improve the anti-diabetic potential of soybean extract, potentially through modulation of the phenolic profile of the extract, and further suggest that enzyme inhibitory activity may be linked to phenolic antioxidant mobilization during sprouting and bio-processing. The significance of food-grade, plant-based enzyme inhibitors for modulation of carbohydrate breakdown and control of glycemic index of foods in the context of preventing hyperglycaemia and diabetes mellitus complication such as hypertension in the long-term is hypothesized and discussed.

Wang et al. (2007) has reported the change in oligosaccharides during processing of soybean sheet. In this study, effect of processing unit operations on level of soybean oligosaccharides during production of soybean sheet were investigated. The concentration of oligosaccharides in initial raw soybean was: sucrose 43.05 g/kg, raffinose 7.52 g/kg and stachyose 41.32 g/kg (in dry matter). Oligosaccharides losses in the soaking water, in the first filtrating stage, in the second filtrating stage and finally in the sheet formation stage were 0.68, 10.3, 8.15 and 47.22 g/kg (initial dry soybean) respectively, representing 0.74, 11.21, 8.87 and 51.39 % reduction of the total oligosaccharides present in the initial soybean. The recovery of oligosaccharides in the final soybean sheet from the initial soybean was 27.92 %. The loss of oligosaccharides was associated with water/matter removal in production process. The analysis of loss profile implied possible ways to improve the technology of production of oligosaccharides-enriched soy sheet.

Sadana et al. (2008) has reported the nutritional evaluation of germinated wheat and soybean based supplementary foods. An experiment

was conducted to develop and evaluate the energy and protein rich supplementary foods. Products namely Seviyan, Halwa, Pinjiri and Pinni were developed using combination of germinated wheat and soybean and carrot powder for 4-6 years old children. Organoleptic evaluation, proximate composition, *β-carotene,* iron and calcium were determined using standardized methods. The result revealed that overall acceptability scores were maximum for sevian (4.26 ± 0.33) and minimum for Halwa (3.79 ± 0.07). However, when statistically was tested, significant differences were observed in the overall acceptability of these germinated products, the protein, fat, carbohydrate, iron, calcium and *β-carotene* content of products ranged from 8.3 to 14.9 g, 18.5 to 31.2 g, 47.1 to 62.4 g, 3.40 to 7.21 mg, 66.0 to 128.4 mg and 1021 to 1322 mg/100 g, respectively. Energy content of prepared foods varied from 454 to 532 kcal/100 g being lowest for Seviyan and highest for Halwa. Contribution towards energy was directly related with the higher fat content of prepared formulation.

2.6 Snacks Food

Snack, defined as a light meal eaten between regular meals include a broad range of products that can take massy forms. Snack foods are an integral part of the diet and have been, over a period of time, commercially exploited on a wide scale.

Most snack foods in market are cereal based, ususally corn, wheat, rice, potato, tapioca or oats. Cereal and legume-based products were found to have acceptable quality (Gandhi et al., 1983). In India, different types of deep fat fried snacks like potato chips, fryums, *papad, kurdais, bhujia, pakkoda, puri, bada, samosa, jalebi, kachori* and sweets such as *murukku, methupakkoda, sev* and *laddu* are very popular. However, the main sector, which is defined clearly as snack foods, contains the major snack products such as popcorn, potato chips or crisps and baked or fried snacks and starch-based snacks.

A traditional technology grew up in the Americas where maize or Indian corn was a major cereal crop. The grains of maize were cooked in water until they softened and could be separated from their hulls and milled into dough. This dough was rolled into thin layers, cut into pieces and baked or fried to

form tortilla chips (Sharma, 1998). These traditional products were dry and crispy and pleasant to eat. Extrusion cooking and ancillary processing machines have enabled these products to be taken from the cottage industry scale to be mass-produced at the rate of several tons per hour and to be made in many variations of form and recipes. For the modern industry, there are several forms of snack products. The major types of snack foods which includes formed dough products from maize derivatives, half-product or pellet snacks, biscuits and breadsticks, directly expanded extruded snacks, popcorn and puffed wheat etc.

A nutritious soy fortified snack with good texture and good protein quality was achieved from a formula containing 18 % of soy flour (9 % DFS + 9 % FFS) replaced in a blends of corn grit and broken rice, 2 % soybean oil and fortified with a mixture of vitamins, minerals and amino acids. Mixed ingredients were adjusted to 16.5 ± 0.5 % moisture content and fed at 365 g/ min to extrusion process at 165-167 ℃with melting temperature employing Bernstorff laboratory twin screw extruder operated at 300 rpm. The obtained snack had expansion ratio (ER), bulk density (BD) and compression force (CF) of 3.9, 58 g/L and 60.17 N, respectively and was subsequently sensory evaluated (9-point hedonic scale) for preference and acceptance together with control samples and popular market snacks. Snack sample from formula 8 had gained the highest score in color, flavor, texture and overall acceptability ($P \leq 0.05$). Protein content in the developed snack sample is 9.9 % which was 46.67–70.69 % higher than in the market snacks (Boonyasirikool and Charunuch, 2000).

Saimanohar et al. (2005) prepared a high protein nutritional baked snack food comprises of vegetable sources as wheat flour, roasted peanut paste, sesame seed, soybean flour and well balance mixture of vitamins, minerals and others. Ingredients were mixed to get homogeneous dough. Dough was sheeted and cut using circular die of 3-4 mm diameter. It was baked at 180-220 ℃ for 4-6 min.

Nath (2006) reported that the increasing consumption of fried foods contributes to a high intake of fats and oils. Because consumers wish to

reduce their consumption of fats and oils pans are offered on the market that does not require any fat.

Pardeshi (2008) developed a cold extrudate from rice plus 7.5 % soy and wheat plus 5 % soy flours at moisture content of 0.54 kg/kg dm and 0.60 kg/kg dm, respectively and the steamed cold extrudate were puffed in hot air puffing system. The rice based cold extrudate could be puffed at 224 ℃ in 28 s and wheat based cold extrudate could be puffed at 115 ℃ in 25 s. The puffed product required oven toasting to impart crispiness. The product could be stored well in metallic polyester of 140-150 g at 30 ℃ in 65 % RH for about 7 months safely.

Omwamba and Mahungu (2014) developed a protein-rich ready-to-eat extruded snack from a composite blend of rice, sorghum and soybean flour. Cooking was carried out at barrel temperature of 110-150 ℃, screw speed of 350-450 rpm, and feed moisture of 12-14 % to investigate the effect of extrusion conditions on physical properties (expansion ratio and bulk density) of a rice, sorghum and soy flour blend.

Arunkumar et al. (2015) developed a blend of sorghum and soybean flours were processed in a co-rotating twin screw extruder to prepare expanded product. Response surface methodology (RSM) was used to study the effect of soya level (SL), feed moisture (FM), barrel temperature (BT) and screw speed (SS) on extruder system parameters and physical properties of the extrudate. Response variables were product temperature (PT), motor torque (MT), specific mechanical energy (SME), expansion ratio (ER), bulk density (BD), hardness (H), crispness (C), water absorption index (WAI), and water solubility index (WSI). Second order polynomial models were developed to determine the responses as a function of process variables. FM, BT, and SS had a significant effect on all the responses except BT on WAI, while SL considerably affected ER, BD, H, C, and WAI. All the models were found to be statistically significant (R^2>0.85; insignificant lack of fit). Sorghum-soya extruded product was found to be feasible and the optimum values of processing variables were: SL:14 %; FM:14 % (wb); BT:129 ℃; and SS:422 rpm.

2.7 Puffing Methods

The puffing process can be broadly classified as atmospheric pressure process with sudden application of heat and pressure drop process (Matz, 1970). The sand puffing, air puffing, oil puffing and roller puffing are examples of atmospheric pressure processes (Chandrasekhar, 1989) while gun puffing is the example of pressure drop process (Hoseney, 1986).

The sand or oven puffed/ popped products are quickly processed but they impart contamination of the product with sand while gun-puffing demands extremely high pressure for its working. The extrusion puffing is highly sophisticated and requires very high operating pressure and temperature. Puffing will ideally create an aerated, porous, snack-like texture with the added benefits of dehydration. Blending the puffed products with different flavours and marketing them in moisture impermeable plastic film pouches provide enormous opportunities for increasing acceptance and usage of puffed products (Arya, 1992). Puffing can be used as an intermediate step during normal dehydration to create a porous structure inside fruits and vegetables. The mass transfer in puffed vegetables, specifically potatoes, during puffing at 130 ℃ resulted in higher moisture removal than that observed for the conventional drying process. This difference was due to physico-chemical and structural modifications induced by the puffing process (Shilton and Niranjan, 1994).

2.7.1 Sand puffing

In sand roasting method, pre-gelatinized cereals are exposed to hot sand, while temperature of sand is about 250 ℃. Due to sudden thermal gradient, the moisture inside the grains vaporizes and tries to escape through the micro pores, expanding the starchy endosperm in size in this process (Chinnaswamy and Bhattacharya, 1983a). In India, work on puffing of paddy has been carried out by Srinivas and Desikachar (1973) and Srinivas et al. (1974). They standardized a laboratory procedure for preparing small puffed paddy samples by sand roasting for the purpose of evaluation. Their study revealed that maximum expansion in puffing of paddy could be achieved by using fully mature, crack free grains having moisture content of 14 % (wb) and roasted at an optimum sand temperature of 275 ℃.

Bhashyam (1982) studied the sand puffing of paddy and rice using a coffee roaster modified for this purpose. Chinnaswamy and Bhattacharya (1983) also used similar sand roaster during their studies for optimizing the processing conditions for rice puffing. They reported optimum conditions for sand puffing of rice at 250 ℃ for 2.5 min. for best expansion. The hydro thermally treated rice at 10.5-11 % moisture content can be puffed in sand at 250-260 ℃ temperature (Chandrasekhar, 1989). In fluidized bed popping, it was not only influenced by the moisture content, but also by the moisture in the heating media (Konishi et al., 2004).

2.7.2 Oven puffing

Oven puffed rice was made from raw or parboiled milled rice, which was cooked with the adjuncts for 1 h at 15-18 lb/in^2 in a rotary cooker until uniformly translucent. It was dried to 0.4286 kg/kg dm moisture content, tempered for 24h and again dried to 0.25 kg/kg dm moisture content. The dried rice was subjected to radiant heat to plasticize the outside of the grain. The grain was 'bumped' through smooth rolls, just sufficiently to flatten and compress it and then surface dried to about 0.1765 kg/kg dm moisture content and tempered for 12-15 hour at room temperature. The bumped rice then passed to the toasting oven, where it remained for 30-90 s. The temperature in the oven was about 300 ℃ in the latter half of the oven-cycle. Due to the bumping, which has compressed the grains, and the high temperature, the grains immediately puff to 5-6 times their original size. The puffed grains were cooled, fortified with vitamins and minerals, if required, and treated with antioxidants (Hoseney, 1986; Juliano and Sakurai, 1985).

2.7.3 Air puffing

Ready-to eat dehydrated puffed potato cubes with long shelf life was developed with high temperature short time (HTST) whirling bed treatment using CCRD. The optimum puffed product qualities in terms of volume expansion (2.6 times), toughness, colour and ascorbic acid loss were obtained at an air temperature of 210 ℃, air velocity 3.76 m/s and retention time of 80 s (Mukherjee, 1997).

Puffing of cereals results from the sudden expansion of moisture present in the interstices of the starch granules during the high-temperature-short-time (HTST) heating of the grains (Chandrasekhar, 1989). The preferred grains for puffing are rice, wheat, oats or pearl barley, which are prepared by cleaning, conditioning and reperceiving (e.g. by a wet scouring process). Flavouring adjuncts (sugar, malt syrup, salt, etc.) are added as for flaked products (Kent and Evers, 1994).

Nath et al. (2007) developed HTST air puffed potato snacks. They prepared the cold extrudate from potato powder at moisture content of 0.581 kg/kg dm and puffed optimally in whirling bed HTST air puffing system at air velocity of 3.99 m/s at temperature of 235.46 ℃ in 51.11 s.

Intensive heating during the puffing process has traditionally soybean accomplished using heated sand (Hoke et al., 2005), superheated steam (Mariotti et al., 2006).

The whirling bed hot air puffing was employed at 200 to 240 ℃ at constant whirling air velocity of 3.97 m/s for the 50 s of puffing duration to successfully develop a soy fortified rice-based cold extrudate, after requisite steaming, was puffed in whirling bed of hot air using the HTST whirling bed puffing system by Pardeshi and Chattopadhyay (2014).

2.7.4 Gun puffing

Cording and Eskew (1962) reported that puffing of vegetables is generally carried out by explosion puffing technique which helps in rapid dehydration of relatively large sized particles by formation of porous structures which have better dehydration characteristics (Jayaraman and Dasgupta, 1992). Explosion puffing includes initial air drying of the product to moisture content of 0.175 to 0.538 kg/kg dm, heating under pressure in a steam gun and quickly releasing the pressure which causes rapid release of vaporizing moisture, resulting in expansion of the product (Eskew et al., 1962; Hailand et al., 1977). The porous structure reduces further drying time by about 40 %. Rehydrated fruit and vegetable pieces made by this process compare well in colour, flavour and texture with freshly cooked counterparts (Sullivan et al., 1974). Sullivan et al. (1981) optimized explosion puffing of carrots, which

showed that good quality products could be obtained at a pressure of 131 kPa, temperature of 188.6 ℃ and initial moisture content of 0.458 kg/kg dm. Sullivan et al. (1974) observed that potatoes prepared by this process exhibited good storage stability up to one year. Sullivan et al. (1977) developed a technique for continuous explosion puffing of potatoes (10 mm, at 0.351 kg/kg dm moisture content) with a capacity of 454 kg/h, which have good quality products. Saputra et al. (1991) used high pressure carbon dioxide in place of steam for explosion puffing of green bell peppers. The study reveals that moisture content of 0.65 to 1.00 kg/kg dm, dice size of 6.35 mm and Carbon-di-oxide pressure of 6.48 MPa gave the best product quality items of dehydration ratio.

For gun-puffing, long-grain white rice or parboiled medium-grain rice is generally used. Puffed parboiled rice has a darker, less acceptable colour and tends to undergo oxidative rancidity faster than puffed raw rice, but parboiled rice requires less treatment, viz. lower steam pressure and temperature, than raw rice. A batch of the prepared grain is preheated to 521-638 ℃ and fed to the puffing gun (Juliano and Sakurai, 1985). Whole-grain wheat, rice or oats is prepared by cleaning, conditioning and reperceiving. Alternatively, dough made from maize meal or oat flour blended with tapioca or rye flour is made to a stiff consistency (0.4286-0.5385 kg/kg dm moisture content), with the addition of sugar, salt and sometimes oil. It is cooked for 20 min at 20 lb/in^2 (137.9 kN/m^2) pressure, dried to 0.163-0.191 kg/kg dm moisture content, and pelleted by extrusion through a die. A batch of the prepared grain or pelleted dough is fed into puffing gun (Kent, 1975). Puffing gun is a pressure chamber with an internal volume of 0.5-1.0 ft^3, which is heated externally and by injection of superheated steam, so that the internal pressure rapidly builds up to about 200 lb/in^2 (1.379 MN/m^2) at temperatures up to 242 ℃, and the starch in the material becomes gelatinized. The puffed product is dried to 0.309 kg/kg dm moisture content by toasting, then cooled and packaged (Fast, 1987; Fast and Caldwell, 1990). Moreover, the material at the moment before expansion requires cohesion to prevent shattering and elasticity to permit expansion. Adding starch, which has cohesive properties, can vary the balance between these two characteristics (Kent and Evers, 1994).

Large grain size wheat preferred for puffing on account of its higher expansion during puffing, but durum wheat may also be used. The wheat is pre-treated with about 4 % of a saturated brine solution (26 % salt content) to toughen the bran during preheating and make it cohesive, so that the subsequent puffing action blows the bran away from the grain, thereby improving its appearance (Fast and Caldwell, 1990).

When structural characteristics of pregelatinized rice flour produced by gun puffing compared with hot air puffing method for three varieties and found that gun puffing method resulted in structural disintegration of starch granules, which affected the pasting properties. Similar results were reported by Mariotti et al. (2006), who has investigated the changes associated with gun puffing method for different grains

2.7.5 Oil puffing

Oil puffing, especially deep fat frying, has become the most popular food preparation technology during the last five decades. The reason is that the preparation is easy even for less experienced cooks and the finished product is highly palatable. Frying is basically a dehydration process. During deep fat frying, the fat acts as heating medium and it is immiscible with water. Most of the food materials contain a lot of water. Because of high temperature, water within the food material gets heated and pumped out into the surrounding oil in the form of steam (Varela et al., 1988). In the frying procedure, fat is the medium of heat transfer. There are two main frying methods, namely shallow frying and deep frying. In case of shallow frying, the layer of frying oil is about 1-10 mm thick in a pan and the fried food is only partially immersed; it has to be turned during the process to obtain an evenly cooked product. The frying takes about 5-10 min, and frying oil is used for greasing the food as it is cooking. The oil is not reused. In case of deep frying, the layer of frying oil is 20-200 mm thick or greater and the fried material is immersed in oil or floats on the surface. The frying again takes about 5-10 min, depending on the dimensions of the food being fried and on the temperature. After frying, the food is removed and the frying oil is used again for the next frying. The duration of use depends mainly on the frying medium, the technical equipment and on the food.

The increasing consumption of fried foods contributes to a high intake of fats and oils. Because consumers wish to reduce their consumption of fats and oils pans are offered on the market that does not require any fat. When these are used the heat transfer medium is not oil and therefore, the process should not be regarded as frying but as roasting. During frying, fat or oil is preheated to temperatures of 150-180 ℃. In contact with oil, fried food is heated rapidly in the surface layers to the temperature of the frying oil. The temperature reaches only 80-100℃ in inner layers (Nath, 2006).

Chattopadhyay et al. (2004) reported that the maximum expansion ratios of 1.98 and 1.96 and maximum mean sensory scores of 6.83 and 6.5833 were recorded at frying temperature of 255 ℃ and 180 ℃ with frying time of 4.5 s and 14 s for cylindrical fryums and star shaped fryums, respectively. They also found that potato flakes could be fried satisfactorily at 205 to 255 ℃ with decreasing frying time from 4 to 2 s, giving ER ranging from 1.65 to 1.79. The ER along thickness always remained higher than the longitudinal ER of cylindrical fryums and diametrical ER of star shaped fryums and potato flakes at all the frying temperatures.

Deep fat frying is a complicated thermo-chemical process producing fried foods with desirable colour, flavour, and texture (Fritch, 1981). Fryums have crunchy wafer-like taste and are normally consumed after frying as snack food. Most of the Indian traditional snack foods are made by deep fat frying (Pushpamma and Geervani, 1981). Several other studies have been conducted on deep fat frying viz., by Bhat and Bhattacharya (2001) on *Boondi* and by Rice.

2.8 Oven Toasting

Oven toasting is commonly used in snack food for increasing crispness of the products. In this process, products lose moisture content and thereby shelf life of the final product increases. Oven toasting is generally done for specific period and with particular temperature with the help of different types of oven depending upon product characteristics and quantity.

Mukherjee (1997) reported that oven toasting increased crispness of the dehydrated puffed potato cubes and the optimum levels of treatment

parameters (temperature 121.21 ℃ and time 16.55 min) for maximum crispness (42.12 N/mm) as obtained by applying response surface methodology.

Nath and Chattopadhyay (2007) developed ready-to-eat potato-soy snacks with high temperature short time air puffing process followed by oven toasting conducted with varying temperature (85.86-114.14 ℃) and time (12.69-35.31 min) based on central composite rotatable design. The final product was evaluated in terms of quality attributes such as crispness, moisture content, ascorbic acid loss, colour values and overall acceptability. The optimum product qualities in terms of crispness (38.7), moisture content (3.35 %, db), ascorbic acid loss (20.87 %, db), L value (52.03) and overall acceptability (7.8) were obtained at temperature of 104.4 ℃ and time of 27.9 min.

2.9 Microwave puffing

The microwave popping ratio and expansion volume of dried rice increased with an increase of the storage time and also the amounts of alcohol or sodium chloride added (Chang and Chien, 1997).

Swarnakar et al. (2014) studied microwave popping characteristics of a particular variety of paddy using a domestic microwave oven. The maximum popping percentage of 63.47 % was obtained at a moisture content of 14.15 % and energy level of 80 kJ (1000 W and 80 s) while the maximum expansion ratio of 4.42 was obtained at 14.94 % moisture content and energy level of 68 kJ (850 W and 80 s). Optimum values of microwave power, time of heating and moisture content of paddy were achieved at 1000 W, 80 s and 15 % respectively, corresponding to popping percentage and expansion ratio of 58.73 and 3.58.

The experiment was conducted to develop cold extrudate, followed by microwave puffing and subsequently by oven toasting to prepare RTE fasting foods. The microwave puffed product was well comparable with products available in market as per the sensory evaluation. The fat and ash content were least affected due to processing while protein content was found to be decreased due to oven toasting. The oil content in microwave puffed product

was considerably less as compared to that in oil fried product (Dhumal, 2010; Dhumal et al., 2014).

Pawar et al. (2014) optimized process parameters of microwave puffed sorghum based ready-to-eat food. The optimal microwave puffing of the steamed cold extrudate could be conducted by convective heating at 210 ℃ for 240 s followed by microwave heating with 80 % of total power of 1350 W for 60 s. The microwave puffed product at optimal process condition had moisture content of 0.2374 kg/kg dm, hardness 1620.72 g, crispness 22 (+ve picks) and expansion ratio 2.04.

2.10 Volume Expansion of Snack Products

Chandrasekhar (1989) measured the expansion ratio by measuring the bulk volumes of 20 g original parboiled rice and the resulting expanded rice in a 50 mL and 250 mL graduated measuring cylinder, respectively, after tapping the cylinder 20 times on a wooden plank. He found that for air temperature below 240 ℃, puffed rice produced was of inferior expansion and above 270 ℃ the puffed rice obtained was significantly discoloured.

Chandrasekhar and Chattopadhyay (1991) studied 12 Indian rice varieties for varietal effect and found that varieties like *Palmoi, Panloi, Kavirajsal,* etc. were expanded in hot air with expansion ratio of about nine. The expansion ratio was measured as bulk volume of puffed product to bulk volume of unpuffed product.

Segnini et al. (2004) quantified the volume of potato chips, before and after frying, by measuring the displaced volume of a finely granular material (rape seeds) by the volume of the chips. Compaction of the seeds was studied to evaluate the reproducibility and accuracy of the technique. Singh et al., (2003) measured specific volume, of extruded snack foods by sand displacement method, which was used to determine bulk density (g/100 mL).

The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudate (Fan et al., 1996). Similarly, Sawant et.al., (2013) measured the expansion ratio by measuring the diameter of extrudate of 10 random samples with a Vernier calliper.

2.11 Hardness and crispness of snack foods

Iles and Elson (1972) studied potato crispness of chips and cracker-biscuit with 4.3 mm diameter punch and a snap test, respectively and found a decrease in sensory crispness or textural preference as the initial slope decreased. None of these investigators related specific quantitative changes in the crispness (initial slope value) to a critical water content where sensory crispness was lost. Zabik et al. (1979) related breaking strength of sugar snap cookies to crispness at different water activities.

Prince et al. (1994) measured the hardness and crispness of rice-soy crackers using Instron universal testing machine. It was observed that the hardness (highest peak of force-deformation curve) and crispness (steepness of force deformation curve) of rice-soy crackers decreased as percentage of soy in the mix increased. These trends remained sharp up to 30 % soy in the mix, and then slowed down.

For freeze-thaw-dehydrated instant potato cubes, Khodke (2002) considered hardness value as mean peak compression force and measured crispness in terms of major positive number of peaks obtained by Stable Micro Systems Texture Analyzer (using cylindrical probe of 35 mm). For biscuit, cereal based products and potato chips, she reported the acceptable values of hardness and crispness ranging between 3000 to 4000 g and 35 to 40 (+ve peaks), respectively, were reported.

2.12 Color Measurement

Nsonzi and Ramaswami (1998) measured the colour of osmo-convective dried blueberries as L, a and b, directly on the product surface, using a Minolta Chroma meter. They computed colorimetric ratio (a/b) to represent the blueness and redness of the blueberries. The total colour difference (ΔE) was determined using the following equation:

$$\Delta E = \left[\Delta L^2 + \Delta a^2 + \Delta b^2\right]^{1/2}$$

Hunter Lab colour meter was used to determine the colour of freeze-thaw-dehydrated instant potato cubes (Khodke, 2002). The L-values, which

denotes degree of whiteness (black=0 and white=100), was chosen to represent the colour of samples.

Yam and Papadakis (2004) presented a simple method that uses a combination of digital camera, computer, and graphics software to measure and analysed the surface color of food products. The method has also the advantages of being versatile and affordable. The images of the food products can be displayed on computer screen or printed on paper for qualitative analysis of colour and structure. Quantitative information such as colour distribution and averages can also be determined readily. Sawant et al., (2013) used the mix containing the least amount of finger millet flour (10 %) had the lightest colour (highest L value) as indicated by Hunter Colour Flex Meter.

Katherine et al. (2006) given that RGB digital cameras obtain information in pixels, this article presents a computational solution that allows the obtaining of digital images in L*a*b* color units for each pixel of the digital RGB image. On the basis of the construction of models, it is possible to find a L*a*b* color measuring system that is appropriate for an accurate, exacting and detailed characterization of a food item, thus improving quality control and providing a highly useful tool for the food industry based on a color digital camera.

2.13 Packaging and Storage Studies

Sullivan et al. (1974) conducted storage studies to evaluate the stability of explosion-puffed, dried potato dice with regard to the development of browning and off-flavour. The results of this storage test show that all samples stored at 23 ℃ or lower, regardless of the package atmosphere, remain stable with regard to browning and flavour throughout the 1-year period.

The keeping quality of the prepared product depends to a large extent on the content and keeping quality of the oil present in it. Thus, products made from cereals having low oil content (wheat, barley, rice, maize grits: oil content 1.5-2.0 %) have an advantage in keeping quality. Severe heat treatment, as in toasting or puffing, may destroy antioxidants or induce formation of pro-oxidants, stability of the oil being progressively reduced as

treatment temperature is raised, treatment time lengthened, or moisture content of the material at the time of treatment lowered (Cooper, 1988).

Another form of deterioration of breakfast cereals after processing and packaging is moisture uptake, which causes loss of the distinctive crisp texture. Moisture uptake is prevented by the use of the correct type and quality of moisture vapour-proof packaging materials (Fast, 1987).

Mukherjee (1997) and Khodke (2002) used metalized polyester (MP), high density polyethylene (HM) and low-density polyethylene (LD), for HTST hot air puffed potato cubes and instant potato cubes, respectively and found MP to be highly suitable for packaging of a product followed by HM.

2.15 Response Surface Modelling and Optimization Technique

RSM is an empirical statistical modelling technique employed for multiple regression analysis using quantitative data obtained from properly designed experiments to solve multivariable equations simultaneously. RSM (Box and Hunter, 1957, Khuri and Cornell, 1987) is used to optimize the parameters based on several responses. The response surface procedures are a collection involving experimental strategy, mathematical methods and statistical inference which when combined enable the experimenter to make an efficient empirical exploration of the system in which he is interested. RSM is a statistical procedure frequently used for optimization studies. It uses quantitative data from an appropriate experimental design to determine and simultaneously solve multivariate problems. RSM designs help in quantifying the relationships between one or more measured responses and the vital input factors. The response surface method produces a mathematical model that can be used to predict a response.

The model equation describes the effect of the test variables on the responses, determine interrelationships among test variables and represent the combined effect of all test variables in the response. This approach enables an experimenter to make efficient exploration of a process or system. Optimization of any process is searching for a combination of factor levels that simultaneously satisfy the requirements of each of the responses and factors.

Simultaneous optimization of multiple responses can be performed graphically or numerically.

Myers (1971) studied central composite rotatable design (CCRD) is a response surface methodology for fitting a second order model to a data set without needing to use a complete 3*k* factorial experiment. After the necessary experiment is created, multiple linear regressions are performed. Coded variables are to be used in this method. A second order polynomial was used to analyses the data and three-dimensional graphs were generated from regression equations over the range of variables tested.

A rotatable central composite surface response design with four variables and five levels was used to characterize the corn fiber and corn starch extrudates by Artz et al. (1990). A second order polynomial was used to analyses the data and three-dimensional graphs were generated from regression equations over the range of variables tested.

Mukherjee (1997) used CCRD for conducting HTST whirling bed experiments during the development of RTE dehydrated puffed potato cubes and applied RSM technique to optimize process and response variables while, Sharma (1998) used the same technique during dry conduction heating for the development of instant flour from white maize.

Ravindra and Chattopadhyay (2000) optimized process parameters for osmotic pre-concentration and fluidized bed drying to produce dehydrated quick-cooking potato cubes by using response surface methodology. A solution of 50 % sugar and 10 % salt at 47 ℃ for 4 h was found for osmotic pre-concentration of potato cubes and drying at 140 ℃ for 10 min at 5.3 m/s followed by thin layer air drying at 50-60 ℃ and 0.75 m/s for about 7h were found to be optimum condition.

Khodke and Chattopadhyay (2004) optimized a process for the production of high quality dehydrated instant potato cubes by freeze-thaw-dehydration technology and obtained optimum process conditions for 10x10x10 mm potato cubes were freezing temperature = -24 ℃, thawing temperature = 5 ℃ and drying temperature = 59 ℃ by using response surface methodology.

Baladhandayutham et al. (2009) evaluated the potential use of natural substrates (rice bran) in the solid-state fermentative production of pectinase by using Response Surface Methodology (RSM). The 2^4 five level Central Composite Rotatable Design (CCD) was used to develop a statistical model for the optimization of process variables such as substrate concentration (5-25 % w/w) *X1*, initial pH (3.0-7.0) *X2*, fermentation temperature (25-37℃) *X3* and inducer concentration (2-10 %) *X4* by *Aspergillus awamori* MTCC 0548. The design contains a total of 31 experimental runs involving replications of the central points and organized in a randomized factorial design.

Jaybhaye et al. (2011) carried out the numerical and graphical optimizations for the process parameters of HTST air puffing to obtain puffed product of optimum quality. To perform these, operational criteria was given in the program and simultaneous optimization of the multiple responses was carried out using Design-Expert 8.0. In the criteria, the desired goals for independent variables were set within the range taken for experiments and those for responses were chosen to minimize moisture content and maximize expansion ratio, color, crispness and hardness.

Response surface methodology (RSM) of Box–Behnken design with 27 experimental runs and the desirability function method were used in the osmotic dehydration process of Chinese ginger ***(Zingiberofficinale Roscoe)*** slices in ternary solution of water, sucrose and sodium chloride for maximizing water loss (WL), rehydration ratio (RR) and total phenolic content (TPC) and minimizing solute gain (SG) and hunter color change (HCC) of dehydrated product by Kejing et al. (2013). The results indicated that the optimum operating conditions were found to be process duration of 102 min, solution temperature of 30 ℃, solution concentration of 50 ^{o}B sucrose + 7.31 % sodium chloride and solution to food ratio of 8:1 (w/w). Under this condition, the WL, SG and TPC were 58.8 % (wb), 12.56 % (wb) and 1.46 % (db), while its RR and HCC were 1.59 and 6.55, respectively. The immersion time was the most significant variable for WL, HCC, SG and RR, and for TPC it was temperature ($P < 0.05$).

2.16 Outlook on Fortified RTE snack foods

Table 2. 6 Outlook on Fortified RTE snack foods

Sr. No.	Name of Product	Composition	Optimum Conditions	Source
1	Rice Puffing	Rice	T -250 ℃	Chandrasekhar, 1989
2	Convenience food	Rice flour: Soy flour 55:45	T- 130 ℃ 40 min	Bhole, 1992
3	Pasta	Soft wheat: Cowpea	----	Bergman et al., 1994
4	Bread	Wheat + 5 % soy flour	----	Rastogi & singh, 1987
5	Crackers	Rice- soy		Prince et al., 1994
6	Puffed Potato cubes	Potato cubes	T- 210 ℃, 80 s	Mukharjee, 1997
7	Pellets	Soft wheat: Soy flour 90:10	90 ℃, 70 s	Lee et al., 2000
8	Puffed Potato cubes	Raw Potato cubes	T- 250 ℃, 8.6 s	Varnalis et al., 2001
9	RTE – Dehydrated potato cubes	Raw Potato cubes	Freezing- -5 ℃ Thawing- 4 ℃ Drying -58 ℃	Khodke, 2002
	Snacks	Chestnut+ rice+ cowpea(flour)	T-120 ℃	Sachtti et al., 2003
10	Bread	Wheat flour: soy flour ,90:10	----	Tariqul et. al., 2007
11	Puffed Potato snacks	Potato Power	T- 235.46 ℃, 51.111 s	Nath, 2006
12	Cold extrudate	Rice + 7.5 % Soy flour Wheat+5 % Soy flour	T- 224 ℃, 28 s T- 115 ℃, 25 s	Pardeshi, 2008
13	RTE snack food	Tapioca: Groundnut 80:20	T- 234 ℃, 75 s	Ewale, 2008
14	Snacks	Rice: soy Wheat: soy	T- 200- 240 ℃, 9 - 15 s T-200 -240 ℃, 10-20 s	Pardeshi, 2009
15	High Protein Pasta	Sweet Potato: whey protein conc.: defatted soy flour: fish powder	----	Gopalakrishnan, 2011
16	Puffed Product	Barnyard millet flour: Potato mash: Tapioca Powder 60:37:3	T- 234 ℃, 39 s	Jaybhaye, 2011
17	Puffed Product	Fryums: wheat based	T- 250 ℃	Babar, 2011
18	RTE-Snacks	Potato: soy	T-185-255 ℃, 20-60 s	Nath et. al., 2011
19	RTE- Fasting Food	Barnyard millet: Potato mash 55:45	Steaming- 15 min CH -220 ℃, 275 s MH- 80 % ,60 s	Dhumal, 2012

20	Pasta	Finger millet flour: Sweet Potato power 55:45	Steam -15 min CH -220 ℃, 300 s MH- 70 % ,60 s	Sonone, 2012
21	Pasta	Finger millet flour: Potato mash: Soy flour 45:45:10	Steam -10 min CH -200 ℃, 300 s MH- 90 % ,90 s	Dhurve, 2013
22	RTE food	Finger millet: maize: rice: full fat soy flour 20:50:20:10	Temp- 140 ℃	Sawant et al., 2013
23	RTE snack	Sorghum: soy flour 90:10	Steam -10 min CH -210 ℃, 240 s MH- 80 %, 60 s	Pawar et al., 2014

Table 2.6 Shows the composition used for preparation of RTE snacks was mostly from rice, wheat and really from millet as single component with full fat soy flour used for protein fortification. The keen observation was recorded that only upto 10 % of full fat soy flour possible for preparation of RTE snack foods.

While considering the importance of minerals for growth of human body. Minor millets are the best substitute to increase the mineral availability. Therefore, the necessity of study, to develop the appropriately processed soybean fortified food which not only increase the proteins also increase mineral availability.

CHAPTER III

MATERIAL AND METHODS

This chapter deals with the material selection, equipment and methods used during the experimentation on preparation of ready-to-eat snack food. The process for optimization of RTE snack foods from cold extrudate with respect to steaming, microwave heating, determination of properties of puffed product, analysis of data, shelf life study, etc. is discussed in this chapter.

3.1 Selection of raw material

The refined pearl millet flour, finger millet flour, foxtail millet flour and barnyard millet flour were the primary raw material for preparation of snack foods in the present investigation. Sprouted Soybean used as the secondary raw material to enrich the protein content of the final product.

3.2 Selection of millets and soybean variety

The minor millets were purchased from local market. Soybean ***(Glycine max Cv.JS-335)*** was procured from the Seed Technology Research Unit, PDKV, Akola. This variety has good germination, high yield and resistant to major diseases and pest.

3.3 Preparation of soybean sprouts

The sprouting of soybeans was conducted with respect to its soaking time for four hours in clean water and subsequently rinsing at an interval of 6 hour for 6 to 7 times would be optimum to attain optimal sprouting of soybean (Tayade, 2010; Pardeshi and Tayade, 2013). Plate 3.1 shows the behaviour of single soybean grain during sprouting (Tayade, 2010.)

3.4 Biochemical analysis of Sprouted soybean

3.4.1. Proximate analysis

Proximate compositions and nutritional properties of initial raw material namely, moisture content, protein, fat, carbohydrate (including fibers), ash and energy value etc. required for the present investigation were determined.

a b c d e f g h

a) Raw soybean grain b) Soaked soybean grain

c) 6h rinsing and cleaning d) 12h rinsing and cleaning

e) 18h rinsing and cleaning f) 24h rinsing and cleaning

g) 30h rinsing and cleaning h) 36h rinsing and cleaning

Plate 3.1: Behavior of single grain of soybean during sprouting

3.4.1.1 Moisture content

The moisture content of the sample was determined by using hot air oven (Indosaw, Ambala Make) with temperature range from 0 to 300 ℃. The weighed samples (5-7 g) were subjected to remove moisture at 105 ± 2 ℃ for 24 h. After which, it was kept inside desiccators for cooling to ambient temperature and the change in weight (measured using electronic weighing balance) was noted (AOAC, 1984). The moisture content was expressed as kg moisture/ kg wet matter (wet basis, wb) or kg moisture/ kg dry mater (dry basis, db). Mean of three replications was reported throughout the course of study.

The MC was determined by using following expression

$$MC\ (\%\ wb) = \frac{W_1 - W_2}{W_1 - W_3} \times 100 \qquad \ldots (3.1)$$

Where,

W_1 = Initial weight of the test sample (g)

W_2 = Final weight of the test sample (g)

W_3 = Weight of Petridish (g)

The moisture content obtained in percent, wb was converted into db by using following formula:

$$MC\ (\%\ db) = \frac{MC(\%\ wb)}{100 - MC\ (\%\ wb)} \times 100 \qquad \ldots (3.2)$$

The moisture content was converted in kg per kg dm.

3.4.1.2 Fat content

The crude fat was determined using Soxhlet apparatus (Thimmaiah, 2006). Following the steps as given below.

1. Weigh 2-3 g of dried sample in a thimble (prepared from Whatman No. 1 filter paper) and place it in a Soxhlet apparatus.
2. Connect a dry pre-weighed solvent flask (‘a’, g) beneath the apparatus and the required volume of solvent (petroleum ether, boiling point is 40-60 ℃) or ethyl ether or hexane) and connect to condenser.

3. Adjust the heating rate to give a condensation rate of 2-3 drops and extract for 16 hours.
4. Remove the thimble and retain ether from the apparatus.
5. Evaporate the excess ether from the solvent flask on a hot water bath and dry the flask at 105 ℃ for 30 min.
6. Cool the flask in desiccators and weigh ('b', g).

$$\text{Crude fat or oil content in sample}(\%) = \frac{(b-a)}{\text{Weight of Sample (g)}} \times 100 \qquad \ldots (3.3)$$

3.4.1.3 Ash content

Ash content was determined as per the method given by AOAC (1984); Thimmaiah (2006).

Steps for determination of ash were as follows:

Place clean crucible in a muffle furnace at 550 ℃ for 1 hour.

1. Transfer crucible from furnace to desiccators and cool to a room temperature.
2. Weigh as quickly as possible to prevent moisture absorption (use metal tongs to remove the crucibles after they are ashed or dried).
3. By difference, weigh 2.0 g of sample into tared silica crucible.
4. Place in a muffle furnace and adjust the temperature at 550 ℃ for 6hours.
5. Transfer a crucible to a desiccator and cool to room temperature.
6. When cooled down, weigh the crucible as quickly as possible to prevent moisture absorption.

$$\text{Ash content}\ (\%) = \frac{\text{Final weight}}{\text{Initial weight}} \times 100 \qquad \ldots (3.4)$$

3.4.1.4 Determination of Protein content

Protein Content was determined by AOAC (1984) method NO. 2.049. 2 g of sample was taken in Kjeldahl flask. Two gram of catalyst mixture (1.5 g K_2SO_4 with 0.0075 g Se) and 25 mL concentrated H_2SO_4 was added to it. The flask was placed in an inclined position on the stand in the digestion chamber for digestion. The flask was heated gently over a low flame until the initial

frothing ceases and the mixture was boiled briskly at moderate rate. The heating was continued until the color of digest was pale blue. The digest was cooled and 40 mL of water was added in 5 mL proportion with mixing. The digest was then transferred to 100 mL volumetric flask. The rest of volume was filled with water. A blank digestion without the sample was carried out and the digest was made to 100 mL. Then 5 mL of the digest was taken in a micro-Kjeldhal condenser and 10 mL 30 % NaOH was added to it. 5 mL of 2 % boric acid with 4 drops of mixed indicator was taken in a clean conical flask and placed it under the outline pipe so that the outlet pipe tip should be dipped in the boric acid. After distillation, ammonia escaped with steam, through the condenser, was dissolved into the boric acid solution. The boric acid changes from bluish purple to bluish green as soon as it comes in contact with ammonia. Five minutes later the conical flask was lowered so that the condenser tip was 10 mm above the liquid. After removing from the burner, the excess boric acid was titrated with standard hydrochloric acid (HCl) until the blue color disappeared. The blank distillation and titration were carried out as in the case of the sample.

$$\text{Nitrogen } (\%) = \frac{(\text{Sample titre} - \text{blank titre}) \times \text{Normalityof HCl} \times 14 \times \text{Volume madeup} \times 100}{\text{Aliquot of digestion taken} \times \text{Weight of the dried sample} \times 1000} \quad \ldots (3.5)$$

$$Protein(\%) = Nitrogen(\%) \times 6.25$$

3.4.1.5 Carbohydrates (including fibers) (by difference)

The carbohydrate content (including fibers) was estimated by subtracting the values of protein, ash, and crude fat on dry basis from 100 % dry matter.

3.4.1.6 Calorific value (Energy)

Calorific values (kcal/100 g) of products at various stages of process were calculated by summing up the multiplication of percent protein, fat and carbohydrate present in these materials by 4.04, 9.0 and 4.04, respectively (Mudambi and Rajagopal, 1983).

3.4.2. Trypsin inhibitor activity

It was determined by a simple and rapid Spectro-photometric method (AACC, 1983; Kakade et. al., 1969; 1974).

a. Extraction of Trypsin inhibitor protein: Seeds of Soybean were ground in laboratory mill and the flour obtained was defatted with acetone (1:10 w/v) 3-4 times, air-dried. Defatted flour (100 g) was shaken with 1.0 L (1:10 w/v) of 50 mM sodium phosphate buffer (pH 7.6) in a shaking water bath for 4 h at room temperature and the suspension was centrifuged at 10000 g for 30 min. The supernatant (crude extract) thus obtained was used for degerming the activity of trypsin inhibitor.

b. Assay of trypsin inhibitor activity: The activity of trypsin inhibitor was assayed by determining the residual trypsin activity following the method of Kakade et al., (1969) with slight modifications using BApNA as the substrate and bovine trypsin as the standard enzyme. The reaction mixture contained 0.3 mL diluted trypsin inhibitor (seed extract), 0.3 mL trypsin (2 mg in 40 mL 0.001 M HCL) and 2.1 mL of BApNA (30 mg dissolved in minimum volume of DMSO and adjusting its final volume to 100 ml with 0.05 M Tris-HCL pH 8.2, containing 0.03 M $CaCl_2$) in a final volume of 2.7 mL. The final concentration of BApNA in the reaction mixture was 0.54 mM and the number of trypsin units was 180. After incubating the mixture at 37 ℃ for 15 min in a shaking water bath, the reaction was stopped by adding 0.3 mL of 30 % (v/v) glacial acetic acid. A blank and a trypsin control were run simultaneously. The absorbance was recorded at 410 nm against the blank. Trypsin inhibitor activity (TIA) is defined as number of trypsin units inhibited (TUI).

3.4.3. Non-digestible oligosaccharides (stachyose and raffinose family)

Three sugar contents (sucrose, raffinose and stachyose) were determined in the current experiment using the HPLC-ELSD method (Calculated as per Kawamura et al., 1970).

3.4.3.1 Sugars

Sugars in all products were estimated by Lane and Eynon’s method as reported by Ranganna (1995) and described as follows:

Reagents:

1. Fehling A
2. Fehling B
3. Methylene blue
4. Neutral lead acetate: Dissolved 25 mg of lead acetate in water and added water to solution (45 %) and volume made 500 mL with water.
5. Potassium oxalate: Dissolved 110 g of potassium oxalate ($K_2C_2O_4.H_2O$) in water and solution (22 %) made the volume to 500 mL.

Preparation of extract

Weighed sample of 10 g dissolved in water and made the volume made to 250 mL in a conical flask. Added 2 mL of lead acetate solution, shake well, and kept for 10 minutes. Necessary amount of potassium oxalate was added to remove the excess of lead and filtered through Whatman filter paper No. 1. The filtrate was used for the estimation of reducing sugars.

3.4.3.2 Reducing Sugars

In a conical flask, 5 mL each of Fehling's solution A and B were taken. The sugar extract in burette and titrated against boiling Fehling's solution by using methylene blue as an indicator. The end point was indicated by the appearance of brick red precipitates, Ranganna (1995).

$$\text{Reducing sugars (\%)} = \frac{\text{mg of invert sugar X 100}}{\text{titre} \times \text{weight of sample (g)} \times 1000} \quad \ldots (3.6)$$

a. Standard invert sugar solution: Weighed 9.5 mg sucrose (AR) in to a 1.0 L volumetric flask. Added 100 mL of water and 5 mL concentrated HCl. Allowed it to stand for 3 days at room temperature for inversion and then made upto mark by adding water. Factor for Fehling's solution was determined by titrating equal amounts of Fehling's A and B with invert sugar by using methylene blue indicator and the end point was indicated by the complete discoloration of the indicator.

$$\text{Factor for Fehling's solution(g of invert sugar)} = \frac{\text{Titre} \times 2.5}{1000} \quad \ldots (3.7)$$

$$\text{mg of invert sugar} = \text{g of invert sugar} \times 1000 \quad \ldots (3.8)$$

3.4.3.3 Total Sugars

A measured amount (50 mL) of the extract was taken in a 100mL volumetric flask to which 1.0 mL concentrated HCl was added and kept for hydrolyzation overnight at room temperature. Next day, the solution was neutralized with saturated NaOH solution followed by a drop of phenolphthalein, finally the volume was made upto the mark with distilled water. This solution was then titrated against Fehling's A and B as was done previously in case of reducing sugars. Titer was used to calculate the per cent total sugar using the formulae, Ranganna (1995).

$$\text{Total sugars (\%)} = \frac{\text{mg of invert sugar} \times \text{Dilution}}{\text{Titre (after inversion)} \times \text{Wt.of Sample (g)}} \times 100 \quad \ldots (3.9)$$

3.4.3.4 Non-reducing Sugars- Ranganna (1995)

$$\text{Nonreducing Sugars (\%)} = [(\text{Total Sugar (\%)} - \text{Reducing Sugar})] \times 0.95 \quad \ldots (3.10)$$

3.4.3. Non-digestible oligosaccharides (Raffinose family)

According to calculations verified as per Kawamura et al., 1970

Non-digestible oligosaccharides (Raffinose family, %) = Non-reducing sugar (%) – sucrose (%)

3.4.4. Phytic acid

Determination of phytic acid: Phytic acid was determined by the procedure of Lucas and Markakas (1975) 2.0 g of the sample was weighed into a 250 mL conical flask. One hundred mL 2 % concentrated HCl was used to soak sample for 3 h and then filtered with a Whatman No. 1 filter paper. Ten mL 0.3 % ammonium thiocyanate solution was added into the solution as indicated and titrated with standard Iron II Chloride solution containing 0.00195g Iron/mL, end point observed to be yellow which persisted for 5 min. The percentage phytic acid was calculated thus:

$$\text{\% Phytic acid} = y \times 1.19 \times 100 \quad \ldots (3.11)$$

Where, y = titer value × 0.00195 g.

3.4.4. Minerals

Weighed 1g sample and added 25 mL of diacid mixture containing nitric acid and perchloric acid in (1:5) proportions and kept overnight. Next day, it was digested on hot plate till 1-2 mL solution was left in the flask. Further, the estimation was performed in accordance with instrument setting standardization and reading with reference to manufacturer's specifications. The iron and magnesium were estimated in Atomic Absorption Spectro photometer (manufactured by) Perkin Elmer Model 2380, USA). Sodium and potassium were estimated in Flame Photometer (Corning 410, England). Phosphorus was estimated by photo metrically (Taussky and Shorr, 1953).

3.5 Preparation of composite millet flour

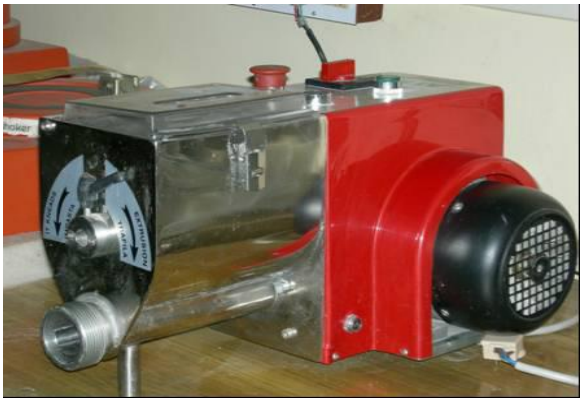
Blends for composite millet flour were prepared from pearl millet flour, finger millet flour, foxtail millet flour and barnyard millet flour. It was sieved though 30 mesh sieves. Best composites flour combination is decided on the basis of micronutrient rich millets and statistical analysis is as shown in Table 3.1 and Table 3.2, respectively. From Table 3.2, the combination given at 'B' offer highest compositional values and therefore the following composite flour is fixed for further experimentation. The moisture content of composite millet flour was found to be 0.0967 kg/kg dm.

Composite Flour with proportion-

1. Finger millet flour (40)
2. Foxtail millet flour (30)
3. Pearl millet flour (20)
4. Barnyard millet flour (10)

Table 3.1: Standardization of formulation of millet flour

Sr. No.	**Ingredients**	**Proportion of Composite mixes (%)**			
		A	**B**	**C**	**D**
1	Pearl millet	10	**20**	30	40
2	Foxtail millet	20	**30**	40	10
3	Finger millet	30	**40**	10	20
4	Barnyard millet	40	**10**	20	30



(A) Dolly Mini P3 Pasta Machine

(B) Kneading chamber with accessaries

(C) Mixing and extrusion accessories

(D) Dough cutting unit

Plate 3.2 Accessories of Dolly Mini P3 Cold Extrusion machine

Table 3.2: Comparative statistical analysis of nutrient composition of millets

Com-potion	Pearl millet	Foxtail millet	Finger millet	Barnyard millet	Average Values						
					Dry matter (g/100g)	Vitamins (mg/100g)	Major nutrients (mg/ 100g)	Trace Elements (mg/100g)	Essential Amino acid (mg/ g of N)	Fatty Acid Com-position (mg/100g)	Average
A	10	20	30	40	84.10	11.98	92.60	1.16	221.55	4.748	69.36[a*]
B	**20**	**30**	**40**	**10**	**87.00**	**15.41**	**117.67**	**1.25**	**252.37**	**7.822**	**80.25** [b]
C	30	40	10	20	87.85	15.65	99.02	1.297	220.21	10.96	72.50 [c]
D	40	10	20	30	86.78	17.48	97.87	1.29	170.67	7.96	63.68 [d]
F-cal											128.78
F-critical											2.77

*The column wise values superscripted by similar letters are at par with each other.

3.6 Preparation of composite flour based cold extrudate

The composite flour was taken in the ratio of finger millet: foxtail millet: peral millet: barnyard millet:: 40:30:20:10 respectively (Table 3.1) and two gram per 100 gram of flour salt was added for taste. The composite flour was mixed together with addition of 55 mL water for cold extrusion (Pawar et al., 2014). The above cold extradate was subjected to steaming for specific time so as to impart gelatinization effect. These cold extrudates were steamed for 10-15 min (Pardeshi, 2008) at 1 kg/cm^2 in kitchen pressure cooker. The prepared mixture of basic ingredients was kneaded for 10-15 min to obtain granular mixture by using Dolly Mini P3 Pasta Machine (LaMonferrina, Italy Make). Appearance of uniform smaller size granules indicates the completion of the kneading process. After the process, the samples were extruded in the pasta machine using rectangular shape die. For each batch of preparation of cold extrudate, 200 g of flour sample was used. Fig. 3.1 shows the process flow chart for preparation of RTE snack foods and Plate 3.2 shows the accessories of Dolly Mini P3 cold extrusion machine

3.7 Experimental design for composite flour based ready-to-eat foods

In the present study, the process variables considered were convective heating temperature (170-210 ℃), convective heating time (120-140 s), microwave power (390-650 W), microwave heating time (140-180 s) on the basis of preliminary trials. The actual input of microwave power was calculated from calibration of the instrument. The calibration of microwave oven was conducted to define the rated power and actual power as given in section 3.7.1. The experimental design was applied after selection of the ranges. Thirty experiments were performed according to a second order central composite rotatable design (CCRD) with four variables and five levels of each variable. Table 3.3 gives the levels of variables in coded and actual units, and Table 3.4 indicates the treatment combinations of variable levels used in the CCRD. Experiments were randomized in order to minimize the effects of unexplained variability in the observed responses due to extraneous factors. The centred point in the design was repeated six times to calculate the reproducibility of the method (Montgomery, 2001).

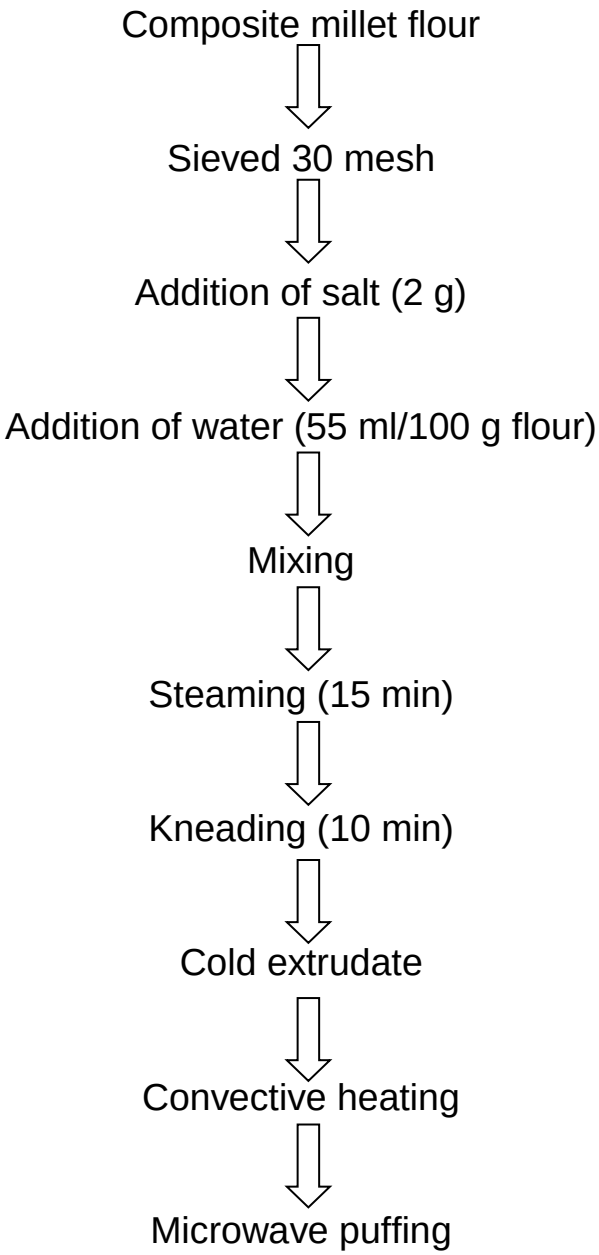


Fig. 3.1 Process flow chart for preparation of RTE snack food

Table 3.3: Levels of variables in coded and actual units

Sr. No.	Name of process variable	Range	Code (X_i)	LEVELS					Interval of variation
				X_1	X_2	X_3	X_4	X_5	
				-2	-1	0	+1	+2	
1	Convective heating temperature (℃)	170-210	X_1	170	180	190	200	210	10
2	Convective heating time (s)	120-140	X_2	120	130	140	150	160	10
3	Microwave power (W)	390-650	X_3	390	455	520	585	650	65
4	Microwave heating times (s)	140-180	X_4	140	150	160	170	180	10

In Table 3.3, the coded levels of process variables are fixed as given below (Myers, 1971);

Coded level for central experiments = 0,

Coded level for factorial experiments =± 1,

Coded level for star point experiments $=\pm 2^{N/4}$

N= No. of variables $= \pm 2^{4/4} = \pm 2$

The actual values of process variables at given coded levels are calculated as below,

$$Ya_{ij} = X_{ij} \times V_i + Ya_3 \quad \ldots (3.11)$$

where,

i = 1 to 4, number of process variables

j = 1 to 5, number of levels

Ya_{ij} = Actual value of i^{th} process variable at given j^{th} coded level

X_{ij} = Coded value of i^{th} process variable at given j^{th} coded level

V_i = interval of variation for i^{th} process variable

Ya_3 = Actual value of i^{th} variable at its central coded level

(X_{i3}) = Average of extremities of range of actual values

Microwave puffing experiments were conducted according to the CCRD design (Table 3.3) and RSM was applied to the experimental data using a commercial statistical package, Design Expert –trial version 10.0.3

(State ease Inc., Minneapolis, USA). The relative effect of the process variables (Convective heating temperature, convective heating time, microwave power, microwave heating time) on the responses was studied and the microwave puffing process was optimized in order to get best quality microwave puffed barnyard millet based ready-to-eat fasting food. The responses studied were final moisture content (MC, kg/kg dm), expansion ratio (ER), hardness (HD, g), crispness (CSP, no. of +ve peaks) and sensory color score (CL).

The following second order polynomial response surface model (Eq. 3.12) was fitted to each of the response variable (Y_k) with the independent variables (X_i)

$$Y_k = b_{k0} + \sum_{i=1}^{4} b_{ki} X_i + \sum_{i=1}^{4} b_{kii} X_i^2 + \sum_{i \neq j=1}^{4} b_{kij} X_i X_j \qquad \ldots (3.12)$$

where b_{k0}, b_{ki}, bk_{ii}, and $bk_{ij}$are the constant, linear, quadratic and cross-product regression coefficients, respectively and X_i are the coded independent variables of X_1, X_2, X_3 and X_4.

3.7.1 Calibration of microwave oven

Determination of Microwave Power Output (Anonymous, 2014). The measurement is made with a water load in a glass beaker. The water temperature is initially below ambient temperature and is raised to approximately ambient temperature by heating in the microwave oven. The data recorded as given in Appendix-II.

Procedure:

1. Measured the weight of an empty 2 L beaker. Add 1,000 ± 5 g of distilled water having an initial temperature of 10 ± 1 ℃.
2. Measured the weight of the beaker to obtain the actual mass of water.
3. Measure the initial water temperature to the nearest 0.1 ℃.
4. Immediately placed the beaker into the center of a microwave oven and operate the oven at full power until the water temperature is 20 ± 2 ℃. Recorded the heating time to the nearest second, excluding the magnetron filament heat-up time.

5. Stir the water and measured the final water temperature to the nearest 0.1 ℃. NOTE: Stirring and temperature measuring devices are to have a low heat capacity
6. Calculated the microwave power output from the formula:

$$P = \frac{4.187 \times m_w \times (T_1 - T_2) + 0.55 \times m_c \times (T_2 - T_0)}{t} \quad \ldots (3.13)$$

Where,

P-Microwave power output, Watt

m_w -mass of the water, g

m_c - mass of the container, g

T_0 -ambient temperature, in ℃

T_1 -initial temperature of the water, ℃

T_2 -final temperature of the water, ℃

t- heating time (s), excluding the magnetron filament heating-up time.

Note: IEC60705 excludes magnetron filament heat-up time, however, for the purposes of this FPI Standard Test Method to Qualify Foodservice Packaging for Use in Microwave Ovens, the filament heat-up time is not considered significant.

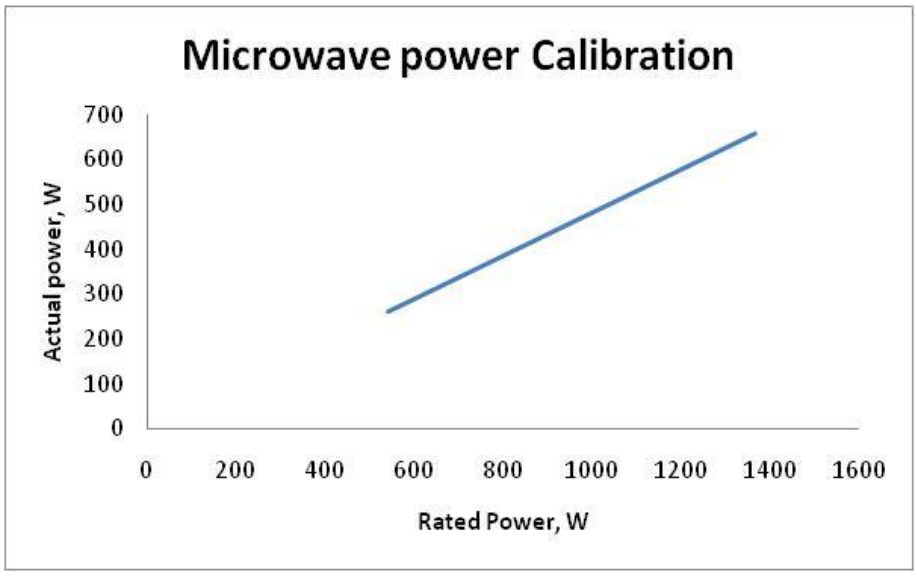


Fig. 3.2 Calibration of microwave oven

Table 3.4: Levels, codes and intervals of variation for Microwave puffing process

Sr. No.	Coded values				Actual values			
	X1	X2	X3	X4	Convective heating temp. ℃	Convective heating time, s	Microwave power (w)	Microwave heating time, s
1	-1	-1	-1	-1	180	130	455	150
2	+1	-1	-1	-1	200	130	455	150
3	-1	+1	-1	-1	180	150	455	150
4	+1	+1	-1	-1	200	150	455	150
5	-1	-1	+1	-1	180	130	585	150
6	1	-1	+1	-1	200	130	585	150
7	-1	+1	+1	-1	180	150	585	150
8	+1	+1	+1	-1	200	150	585	150
9	-1	-1	-1	+1	180	130	455	170
10	+1	-1	-1	+1	200	130	455	170
11	-1	+1	-1	+1	180	150	455	170
12	+1	+1	-1	+1	200	150	455	170
13	-1	-1	+1	+1	180	130	585	170
14	+1	-1	+1	+1	200	130	585	170
15	-1	+1	+1	+1	180	150	585	170
16	+1	+1	+1	+1	200	150	585	170
17	-2	0	0	0	170	140	520	160
18	+2	0	0	0	210	140	520	160
19	0	-2	0	0	190	120	520	160
20	0	+2	0	0	190	160	520	160
21	0	0	-2	-2	190	140	390	160
22	0	0	+2	+2	190	140	650	160
23	0	0	0	0	190	140	520	140
24	0	0	0	0	190	140	520	180
25	0	0	0	0	190	140	520	160
26	0	0	0	0	190	140	520	160
27	0	0	0	0	190	140	520	160
28	0	0	0	0	190	140	520	160
29	0	0	0	0	190	140	520	160
30	0	0	0	0	190	140	520	160

3.8 Evaluation of response parameters

After microwave puffing, composite flour millet based ready-to-eat foods, the various response parameters were considered for the purpose of optimization of process parameters. The response parameters were considered as moisture content (kg/kg dm), Expansion ratio (ER), Hardness (g), crispness (number of +ve peaks) and color (L- values).

3.8.1 Moisture content (MC)

The moisture content of samples at each stage of the process was determined by hot air oven method (AOAC, 2005). For determination of moisture content, the samples taken out of the microwave oven were directly collected in weighed sample box, immediately closed with airtight cap and weighed immediately in order to minimize condensation effect. After 24 hours of drying sample weights were taken. The moisture content was expressed in kg per kg dm. Mean of three replications was reported throughout the experimental study.

3.8.2 Expansion ratio (ER)

The expansion ratio (ER) for all the samples was determined in terms of ratio of average bulk volume *(v)* of puffed product during puffing to the average initial bulk volume *(v_o)* (Chandrasekhar, 1989) of product before introducing in puffing system. For this purpose, the uniform strip (20 mm x 10 mm) size was chosen. The average thickness (1 mm) of 10 strips was determined using vernier caliper.

3.8.3 Textural measurement (hardness and crispness)

The texture characteristics of puffed and oven toasted RTE snack foods in terms of hardness and crispness were measured using a Stable Micro System TA-XT2 texture analyser (Texture Technologies Corp., UK) (Plate 3.13) fitted with a 5 mm diameter circular punch. The studies were conducted at a pre-test speed of 1.0 mm/s, test speed of 0.5 mm/s, distance of 30 % strain, and load cell of 5.0 kg. Hardness value was considered as mean peak compression force and expressed in grams and crispness was measured in terms of major positive peaks (Cruzycelis et al., 1996) with the following settings of Texture Analyzer.

TA.XT-2 Settings

Pre- Test speed 1.0 mm/s

Test Speed 0.5 mm/s

Post-Test Speed 1.0 mm/s

Distance 30 % strain

Tigger Type Auto- 3 g

Data Acquisition

Rate 200 pps

Probe Type 2.5 mm diameter circular punch

Load cell 5 kg (hardness and crispness)

For measurement of crispness a macro was developed which counts number of major peaks obtained in the product during compression. Average values of ten replications are reported.

3.8.4 Color

The color (L-value) and was measured hunter lab colorimeter (Khodke, 2002). L-values, which denotes degree of whiteness (black=0 and white=100), was chosen to represent the colour of samples.

3.9 Data analysis and optimization

Regression analysis and analysis of variance (ANOVA) were conducted for fitting the models represented by Eqs. 3.11 and 3.12 and to examine the statistical significance of the model terms. The adequacy of the models was determined using model analysis, lack-of fit test and R^2 (coefficient of determination) analysis as outlined by Lee et al. (2000) and Weng et al. (2001). The lack of fit is a measure of the failure of a model to represent data in the experimental domain at which points were not included in the regression or variations in the models cannot be accounted for by random error (Montgomery, 2001). If there is a significant lack of fit, as indicated by a low probability value, the response predictor is discarded. The R^2 is defined as the ratio of the explained variation to the total variation and is a measure of the degree of fit (Haber and Runyon, 1977). Coefficient of

variation (CV) indicates the relative dispersion of the experimental points from the prediction of the model. Response surfaces and contour plots were generated with the help of commercial statistical package, Design Expert - trial version 10.0.3. The numerical and graphical optimization was also performed by the same software.

3.10 Numerical optimization

Numerical optimization technique of the Design-Expert software was used for simultaneous optimization of the multiple responses. The desired goals for each factor and response were chosen. The goals may apply to either factors or responses. The possible goals are: maximize, minimize, target, within range, none (for responses only). All the independents factors were kept within range while the responses were either maximized or minimized. In order to search a solution optimizing multiple responses, the goals are combined into an overall composite function, D(x), called the desirability function (Myers and Montgomery, 2002), which is defined as:

$$D(x) = (d_1 \times d_2 \times ....\times d_n)^{1/n} \quad \ldots (3.14)$$

where d_1, $d_2 \ldots d_n$ are desirability of responses and n is the total number of responses in the measure.

Desirability is an objective function that ranges from zero outside of the limits to one at the goal. It reflects the desirable ranges for each response (d_i). The desirable ranges are from zero to one (least to most desirable, respectively). The numerical optimization finds a point that maximizes the desirability function. The characteristics of a goal may be altered by adjusting the weight or importance (Stat ease, 2016).

Graphical optimization was also carried out for the process parameters for microwave puffing obtaining the best product. For graphical optimization, super imposition of contour plots for all responses was done with respect to process variables using Design-Expert software. The superimposed contours of all responses for convective heating temperature, convective heating time, microwave power and microwave heating time and their intersection zone for minimum final moisture content, maximum expansion ratio, hardness (in the range of -1 and +1 coded values) and maximum crispness indicated the

ranges of variables which could be considered as the optimum range for best product quality in terms of responses. The optimum combination of product and process variables for microwave puffing conditions were derived by averaging those ranges of variables. The graphical optimization of process parameters i.e. temperature and time for oven toasting was also carried out as indicated above. The responses considered were minimum final moisture content, minimum hardness, maximum crispness and maximum sensory colour score.

3.11 Experiments for soy fortification and preparation of millet flour based ready-to-eat food

The optimized parameters using experimentation in section 3.5, was decided form minor millet-based RTE snack. Using these optimized process conditions, sprouted soy percentage was varied (5 %, 10 %, 15 % and 20 %) in composite millet flour to prepare optimally soy fortified composite minor millet flour based snack foods. The responses were measured final moisture content (MC, kg/kg dm), expansion ratio (ER), color (L, a and b-value), hardness (HD) and crispness (CSP) and replicated thrice. The ANOVA (analysis of variance) was used for statistical analysis of data (Montgomery, 2001). Biochemical analysis of optimally developed product was conducted as given in section 3.4.1.

3.12 Nutritional composition analysis

The nutritional composition of the optimally prepared samples at various stages i.e. composite flour before cold extrusion, extrudate before steaming, extrudate before puffing, puffed snack were measured by standard analytical procedures given in section 3.4.1

3.13 Sensory Evaluation

The sensory evaluation of final products was carried out by a panel of available nine members of untrained judges consisting of students and staff of the Dept. of Agricultural Process Engineering, PDKV, Akola. A nine-point hedonic scale (BIS, 1971) was employed for all the attributes evaluated where 9 denoted "liked extremely" and 1 indicated "disliked extremely". The data on

the sensory attributes like taste, flavor, colour, texture and overall acceptability were analysed by analysis of variance (ANOVA).

3.14 Study of mass transfer

As in most studies carried out on drying (if moisture removal during puffing is resembled to that in drying), diffusion is generally accepted to be the main mechanism during the transport of moisture to the surface to be evaporated. The solution of Fick's equation, with the assumptions of moisture migration being by diffusion, constant diffusion coefficients and temperature for an infinite slab (initial shape) (Brooker et al., 1974) is,

$$MR = \left(\frac{M - M_e}{M_o - M_e} \right) = \frac{8}{\Pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(- \frac{\Pi^2 (2n+1)^2 D_{eff} t}{4l^2} \right) \quad \ldots (3.15)$$

Where-M, M_o and M_e are the local, initial and equilibrium moisture content (kg/kg dm), respectively, l is the half of the thickness of flat strip (m), t is the time (min) and D_{eff} is the effective diffusivity (m^2/s).

3.15 Storage of RTE food

Storage studies was conducted on the final products prepared by optimized process conditions at 40 ℃ and 95 % relative humidity temperatures and packaging materials. Metalized polyester (MP) and HDPE used for storage studies, as these materials are known to be fairly good moisture and oxygen resistant and are being used commercially for packaging of crispy snack foods (Dhumal, 2010).

3.15.1 Sorption isotherm of the final product

Sorption isotherm behaviour of the RTE snack foods at ambient condition was studied to show the variation in moisture content with water activity (a_w). Crispness, the main criteria for acceptability of the product corresponding to variation in moisture content was measured in the Texture Analyzer. Critical moisture content and critical water activity where the product lost its crispness was determined through these studies (Pardeshi, 2008).

3.15.2 Determination of water vapor transmission rate (WVTR) of packaging material

The values of permeability for given thickness of the packaging materials was determined by using Eq. 3.16 (Khodke, 2002).

The permeability of packaging material was calculated using following equation:

$$K_A = \frac{\Delta W / \Delta \theta}{P_{out} A'} \quad \text{… (3.16)}$$

where,

W = weight gain by desiccant (g)

θ = time (days)

K_A = permeability (kg m^{-2} day^{-1} Pa^{-1}) for given thickness (x) of the packaging material

A’ = area of the package (m^2)

x = thickness of packaging material (mm)

P_{out} = water vapor pressure at 40 ℃ (Pa)

3.15.3 Shelf life calculation

Shelf life of the product ‘θ’ (days) i.e. period required for the moisture content of the RTE snack foods to increases from an initial value of Mi (kg water per kg dm) to its critical value Mc where it lost its crispness was estimated numerically (Das, 2005).

$$\theta = \frac{W_s}{P^* K_A A'} \int_{M_i}^{M_c} \frac{M}{RH - a_W} \quad \text{… (3.17)}$$

where,

θ = shelf life (days)

W_s = dry matter in the product (kg)

W_{gain}= weight gain due to moisture uptake = Ws (M_c – M_i)

P* = saturation vapor pressure of water at T ℃ (Pa)

$$= \exp\left(23.0603 - \frac{3723.67}{222.857 + T}\right)$$ (Geankoplis, 1983)

K_A = permeability of the packaging material (kg m^{-2} day^{-1} Pa^{-1})

A’ = area of the package (m^2)

RH = relative humidity in which package is placed (fraction)

a_w = water activity (fraction) of the product at T ℃ = f (M)

a_{wc}= critical water activity and is less than or equal to RH

M = Moisture content of the RTE snack (kg water per kg dm)

i and c = are the suffix for initial and critical conditions,

respectively.

CHAPTER IV

RESULTS AND DISCUSSION

This section deals with results of various investigations on development of RTE snack foods from cold extrudate prepared from composite flour of minor millets, biochemical analysis of sprouted soybean during process, optimization of process for microwave oven puffing of cold extrudate prepared from composite millet flour, sprouted soy fortification of optimally prepared puffed product, changes in chemical composition of product during puffing, puffing kinetics, sensory evaluation of optimally developed RTE product and storage studies of RTE snack foods developed.

4.1 Biochemical Profile process of sprouting of soybean

4.1.1 Effect of sprouting process on chemical composition of soybean during sprouting

The moisture content of raw and germinated soybean significantly increased from 11.42 % to 173.03 % on dry basis during germination process (soaking and sprouting) as shown in Table 4.1. Similar results reported by Khatoon and Prakash (2006) in germinated legumes (soybean).

Table 4.1: Effect of sprouting process on chemical composition of soybean during sprouting

Stage of product	Moisture content (MC, % (db)	Protein (%, db)	Fat (%, db)	Ash (%, db)	Carbohydrates+ fiber (%, db*)	Energy kcal/100g product
Raw	11.42[a]	38.58[a]	19.98[a]	5.68	35.76	480.18
After 4 h soaking	124.65[b]	39.19[b]	19.81[a]	4.54	36.45	483.92
After 24 h rinsing	158.76[c]	40.21[c]	17.55[b]	4.95	37.29	471.05
After 48 h rinsing	173.03[d]	42.25[d]	16.01[c]	5.13	36.61	462.68
CD (5%)	0.541	0.115	1.102	NS	NS	--

*by difference

[a]The column wise values superscripted by similar letters are at par with each other

As germination proceeds, legumes took up water from the surrounding the metabolic process to commence. The dry legumes absorb water rapidly, influenced by the structure of the legumes. The increase in water uptake with time is due to the increasing number of cells within the seed becoming hydrated (Nanogaki et al., 2010).

The protein content of sprouted soybean was found to be increased with increase in rinsing time (i. e. from soaking to germination) from 38.58 % to 42.25 % db as shown in Table 4.1. Similar results were found by Kajihousa et al., (2014). According to Chavan and Kadam, 1989, the conversion of storage protein of seed into albumins and globulins during sprouting may improve the quality of seed proteins. Similar result was obtained by Ramadan 2012, after 60h germination period. Kaushik et al. (2010), also reported an increase in protein content with germination of soybean.

The fat content significantly decreased from 19.98 to 16.01 % (db) during germination process as shown in Table 4.1. Similar results of soaking and germination and heating of soybean with decrease in fat where reported by Copeland and Mcdonald (1995). This agree with Echendu et al. (2009) reported on ground beans. However, Ghavidel and Prakash (2007) found a significant decrease of fat content after germination of some legumes seed. Osman (2007) and Mubarkak (2005) reported a significant decrease of fat content of mung bean seed when allowed to germinate for three days. This could be owing to use of fat as energy during the sprouting process. This decrement in oil content might be due to increasing activity of lipase during soaking and germination (Kent and Mc Cready, 1975) as well as the breakdown of oil into glycerol and fatty acid (Lgbedioh et al., 1994). Mostafa et al. (1987) found 6 days germinated soybean had decreased oil content of seed.

From Table 4.1, it was observed that, the ash content and carbohydrates including fiber was non-significantly decreased in germinated soybean. The decrease in ash content represents less in minerals due to rootlet and washing of the soybean in water to reduce the sour smell during the period of germination, similar to the observations of Ramadan (2012). The

energy value was calculated (as given in section 3.4.1.6) of sprouted soybean as 462.68 kcal/100 g.

4.1.2 Effect of sprouting process on anti-nutritional factors of soybean during sprouting

Phytic acid play an important role in minerals availability (Philippy and Jahnston, 1985). The reduction could be due to increase in endogenous phytase activity (Shimelis and Rakshit, 2007, Khattak et al., 2007) depending on different types of legumes. Reduction could be due to diffusion into the soaking of legumes in distilled water on effective way of removing phytic acid from legumes (Liang et al., 2009). Phytic acid was analysed in germinated and non-germinated soybean during germination process and the result was shown in Table 4.2. The reduction in phytic acid from raw to sprout was 269.27 to 251.20 mg/100 g. Similarly, the decrease of phytic acid contents germinated legumes has been frequently reported (Ibrahim et al., 2002, Khattak et al., 2007, Ghavidel and Prakash, 2007).

Table 4.2: Effect of sprouting process on anti-nutritional factors of soybean during sprouting

Sr. No.	Process	Phytic acid (mg/100 g)	Trypsin inhibitor activity (mg/g)	Total Sugars (%)	Non-reducing sugars (%)	Sucrose (%)	Non-digestible Oligosaccharide (Raffinose family) (%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7) = (5) - (6)[#]
1	Raw	269.27[a]	4.43[a]	5.89	5.68	5.13	0.58
2	After 4 h soaking	271.02[b]	3.73[b]	5.56	5.44	4.28	1.23
3	After 24 h rinsing	255.84[c]	2.33[c]	4.69	4.61	4.19	0.44
4	After 48 h rinsing	251.20[d]	0.205*[d]	3.28	3.15	3.08	0.07
	CD(5%)	0.088	0.183	-	-	-	-

*column wise values superscripted by similar letters are at par with each other

[#]Calculated as per Kawamura et al, 1970.

Trypsin inhibitor activity (TIA) was found 4.43 to 0.205 mg/g during germination process, as shown in Table 4.2. The highest content of trypsin inhibitor activity was 4.43 mg/g in raw soybean seed and in sprouted soybean (after 48 h rinsing) 0.205 mg/g. A reduction of TIA was found to be higher in sprouted soybean (after 48 h rising). The percent inhibition was observed about 95 % in sprouted soybean. Therefore, these sprouted soybeans are safe for human consumption. A reduction of about 16% was reported for horse gram, and 40% in the case of moth bean. Similar of reduction was also reported for soy bean during germination by Collins and Saunders (1976).

Non-digestible oligosaccharide (raffinose family) was calculated as per Kawamura et al., 1970 (section 3.4.3). From Table 4.2, a significant reduction of raffinose family oligosaccharides was found in soybean cultivars during germination process i. e. range from 0.58 - 0.07 %. As the period of germination was prolonged upto 48 h, a significant and successive reduction in raffinose family was observed about 88 % of NDO's decreased after 48 h rinsing of soybean. Decrease of raffinose by 80 % and stachyose by 45 % was reported for 16h soaked soybean after 48 h of sprouting, decrease in raffinose by 84 - 90 % (Mulimani et al., 1997). Thippeswamy and Ramalingam (1997) have reported that soaking of whole soybean seeds led to a mean decrease of 80.3 % for raffinose. Similar results were reported in (Sampath et al., 2008). Complete disappearance of stachyose and raffinose in cowpea, pea, black gram, pigeon pea and soybean after 48 h germination. Reddy and Salunkhe (1980) reported complete disappearance of raffinose and stachyose in black gram after 48 h germination which may be due to the hydrolysis of oligosaccharides by α-galactosidase enzyme. Breakdown of raffinose family oligosaccharides by active α- galactosidases in pea seeds during germination and post germination events was reported (Blochl et al., 2008).

4.1.3 Effect of sprouting process on antioxidant of soybean during sprouting

From Table 4.3, it was observed that it was significant increase in phenols during sprouting of soybean i.e. range from 116.86 to 135.24 mg/100 g. The phenolic structures play a crucial role in bioactive activities (Fidrianny

et al., 2014). Particularly, the number and location of hydroxyl groups in phenolic structures inextricably link to antioxidant activity (Silva et al., 2000).

From Table 4.3, total antioxidant activity was reduced non-linearly during the sprouting process i.e. ranged between 2157.59 to 996.86 µg/g. However, phenolic component was not significantly correlated with the antioxidant activity of soybean. Huang et al., (2014) also proved that the antioxidant activity was not correlated with total phenolic component of germinated mung bean and soybean. A possible reason was explained by Randhir and Shetty (2007), who found out that the antioxidant activity might be determined not only by the total phenolic content but also by the qualitative characteristics of phenolic.

Table 4.3: Effect of sprouting process on antioxidant factors of soybean during sprouting

Sr. No.	Process	Phenols (mg/100g)	Total anti-oxidant activity(µg/g)
1	Raw	116.86[a]	2157.59[a]
2	After 4 h soaking	109.47[b]	2131.26[b]
3	After 24 h rinsing	107.75[c]	996.86[c]
4	After 48 h rinsing	135.24[d]	1170.84[d]
	CD (5%)	0.0311	0.025
[a]The column wise values superscripted by similar letters are at par with each other			

4.2 Preparation of flour ingredients

Composite flour was prepared from pearl millet flour, finger millet flour, foxtail millet flour and barnyard millet flour (See section 3.5). It was sieved though 30 mesh sieves. Best composite flour combination was decided on the basis of micronutrient rich millets and statistical analysis was as shown in Table 3.1 and Table 3.2, respectively. The best combination of composite flour was taken in the ratio of finger millet: foxtail millet: pearl Millet: barnyard millet:: 40:30:20:10 respectively. The moisture content of composite millet flour was found to be 0.0967 kg/kg dm.

4.3 Preliminary experimental trials

Preliminary trials were conducted as discussed in section 3.6. The cold extrudate was obtained from composite millet flour to determine the suitability of cold extrudate for its microwave puffing system. From preliminary experiments, it could be said that the selection of cold extrudate at sufficient moisture content, was essential for microwave puffing of cold extrudate, obtained from composite millet flour based materials. However, the satisfactory puffing could not be possible for millet based cold extrudate. This may be due to lack of gluten content in raw material. In order to impart possible gelatinization effect, the steaming of cold extrudate was felt necessary. Therefore, cold extrudate required 15 min of steaming for gelatinization and 10 min kneading for uniform granular mixture to obtain flat and rectangular shaped cold extrudate. The moisture content of this cold extrudate was found to be 0.7442 kg/kg dm (see Table 4.8). The microwave puffing could not be acceptable at higher moisture content. Therefore, to remove the surface moisture, convective heating was required.

Convective heating temperature was taken in the range of 170 to 210 ℃, at and beyond 210 ℃ with respect to time 160 s cause over drying, which retarded the puffing effect. The puffing effect was found to be increasing in both the cases with increase in moisture content of cold extrudate with increase in convective heating temperature 160 ℃ for 120 s. However, at higher moisture contents, the cold extrudate becomes too soft to handle. Considering higher puffing effect and easiness for handling of the fresh cold extrudate, the cold extrudate prepared from composite millet flour at 0.7442 kg/kg dm was considered to be acceptable for further study in the range of 160 to 210 ℃ of convective heating temperature.

4.4 Microwave puffing of cold extrudate to prepare composite millet flour based RTE snack foods

The cold extrudate prepared from refined composite millet flour as mentioned in section 3.6, was steamed and puffed as discussed in section 3.7. The experiment was conducted in CCRD (Table 3.4) with four variables viz., convective heating temperature (CHT, ℃), convective heating time (CHt, s), microwave power (MP, W), microwave puffing time (MPt, s). The response

Plate 4.1: Stage-wise development of composite millet flour based RTE snack food

variables measured for studying the effect and optimization of process parameters were taken as moisture content (MC, kg/kg dm), hardness (HD, g) and crispness (CSP, No. of +ve peaks), expansion ratio (ER), color (L-value). Observations recorded are given in Appendix-III.

4.4.1 Effect of Various Process Parameters on Final Moisture Content (MC, kg/kg dm) During Microwave Puffing

The observations for moisture content with different combinations of the process parameters are presented in Appendix-III. The experimental range of moisture content from 0.0219 kg/kg dm to 0.0632 kg/kg dm was obtained with proportion of 40:30:20:10 basic ingredient (Section 3.5). The model was fitted to the experimental data and statistical significance was calculated for MC as shown in Table 4.4. The regression equation describing the effect of the process variables on moisture content of composite flour based RTE food in terms of actual level of variables are given as.

CHT=Convective heating temperature, ℃; CHt = Convective heating time, s;

MP= Microwave power, W; MPt = Microwave puffing time, s.

Analysis of variance showed that moisture content was dependent significantly on the linear term of convective heating temperature, connective heating time, microwave puffing power and microwave puffing time. Temperature and microwave power were the main factors affecting the moisture content as revealed by the respective regression coefficient and F-value. The R^2 value was calculated and found to be 0.92, showing good fit of model to the data. The lack of fit F-value was non-significant, which indicate that the developed model was adequate for predicting the response. Moreover, the model adequacy evaluated with predicted R^2 of 0.69 showed it to be in reasonable agreement with the adjusted R^2 of 0.88. Therefore, this model could be used to navigate the design space. The regression equation describing the effects of the process variables on MC in terms of actual levels of variables is given in Eq.4.1.

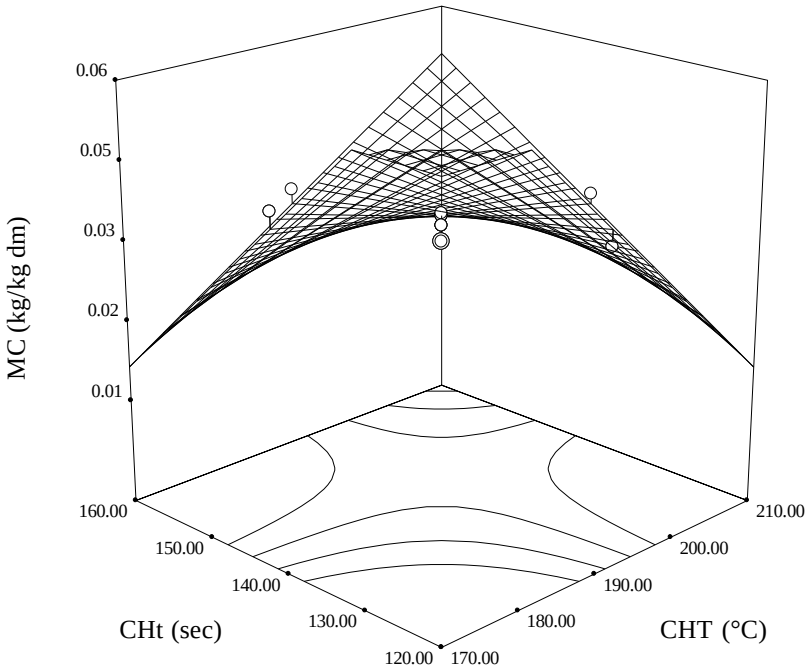


Fig. 4.1A: The contour and response surface plots showing the effect of CHT and CHt on MC (kg/kg dm) for microwave puffing.

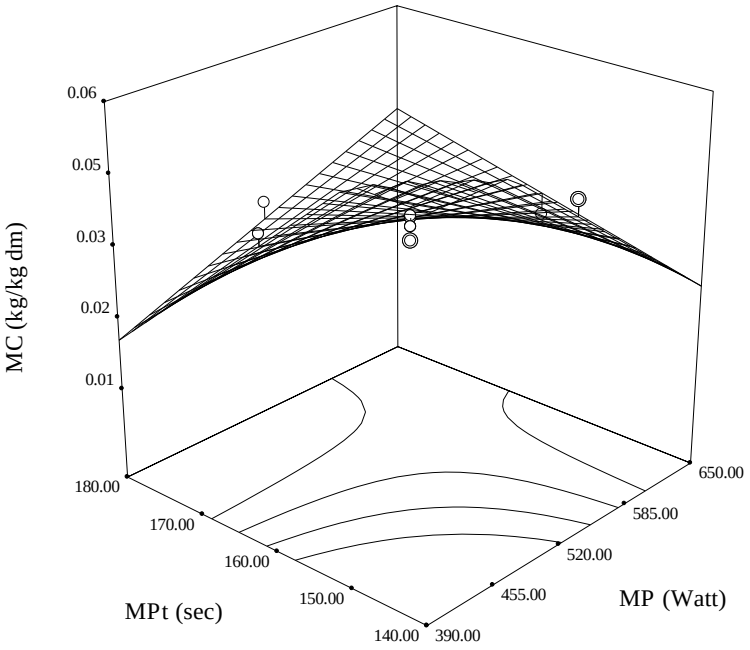


Fig. 4.1B: The contour and response surface plots showing the effect of MP and MPt on MC (kg/kg dm) for microwave puffing.

$$MC = 2.42 - 0.0084 \times CHT - 0.012 \times CHt - 0.0016 \times MP - 0.0023 \times MPt - 6E-05 \times CHT \times CHt - 1.56E-06 \times CHT \times MP - 6.6E-06 \times CHt \times MPt + 1.96E-06 \times CHt \times MP - 2E-06 \times CHt \times MPt - 06 \times MP \times MPt \ldots (4.1)$$

The comparative effect of each factor on the MC could be observed by the F-values in the ANOVA and also by the magnitudes of coefficients of the coded variables (Table 4.4). The F-values indicated that MPt was the most influencing followed by MP, CHT and CHt over MC. To visualize the combined effect of two variables on the MC, the response surface and contour plots were generated for the fitted model as a function of two variables while keeping other two variables at their central values. It could be observed from Fig. 4.1A and Fig. 4.1B, MC decreased with increase in CHT, CHt, MP and MPt. Similar results were also reported by (Dhumal et al., 2014) for RTE barn yard millet and potato-based snack and (Pawar et al., 2014) for sorghum-soy fortified RTE snack.

4.4.2 Effect of Various Process Parameters on Hardness (HD, g) During Microwave Puffing:

The observation for hardness with different combinations of the process parameters are presented in Appendix-III. It varied between 875.05 g and 2356.36 g within the combination of variables. The quadratic model was tried to fit the experimental data and statistical significance for liner, quadratic and interaction terms was calculated for HD as shown in Table 4.4.

The R^2 value was calculated by a least square technique and found to be 0.54, showing that model was not fitting well to the data. The C.V. was 4.31 and lack of fit was significant showing inability of the model fitted to represent the experimentally obtained data. This may be due to softness of product at higher moisture content, irrespective of process parameters.

Therefor this response was not considered for optimization of process condition. Similar results were found in Pardeshi (2008) and Dhumal (2010).

4.4.3 Effect of Various Process Parameters on Crispness (CSP) During Microwave Puffing

It was observed that the value of CSP was ranged between 4.00 and 20.00 with different combinations of the process parameters (Appendix-III). The quadratic model was fitted to the experimental data and statistical significance was calculated for CSP as shown in Table 4.4. The R^2 value was calculated by a least square technique and found to be 0.89, showing good fit of model to the data. The response surface and contour plots were generated for the fitted model (Eq.4.2) as a function of two variables while keeping other two variables at their central values as shown in Fig. 4.2A and 4.2B.

The regression model was fitted to the experimental data and statistical significance was calculated for CSP as shown in Table 4.4 with F-value of 4.984 and R^2 value of 0.88 at high significant level was calculated by a least square technique, showing good fit of model to the data. The lack of fit F-value was non-significant for the model obtained shown in Eq. (4.2). The regression equation describing the effects of the process variables on CSP in terms of actual levels of variables is given as,

$$\begin{aligned} CSP = {} & -1457.38 + 6.058 \times CHT + 8.133 \times CHt + 0.32 \times MP + 2.587 \times MPt \\ & + 0.0025 \times CHT \times CHt + 0.001 \times CHT \times MP \\ & + 0.006 \times CHt \times MPt - 8E - 17 \times CHt \times MP - 6.1E \\ & - 16 \times CHt \times MPt + 0.0002 \times MP \times MPt - 0.02 \times CHT^2 \\ & - 0.03 \times CHt^2 - 0.0005 \times MP^2 - 0.012 \times MPt^2 \ldots (4.2) \end{aligned}$$

The comparative effect of each factor on the CSP could be observed by the F-values in the ANOVA and also by the magnitudes of coefficients of the coded variables (Table 4.4). The effect of MP was most prominent followed by CHT and MPt. Other quadratic and combination terms had effect as shown in Table 4.4. During puffing it was observed that as puffing initiates and advances moisture is trapped in the puffed product and vaporized

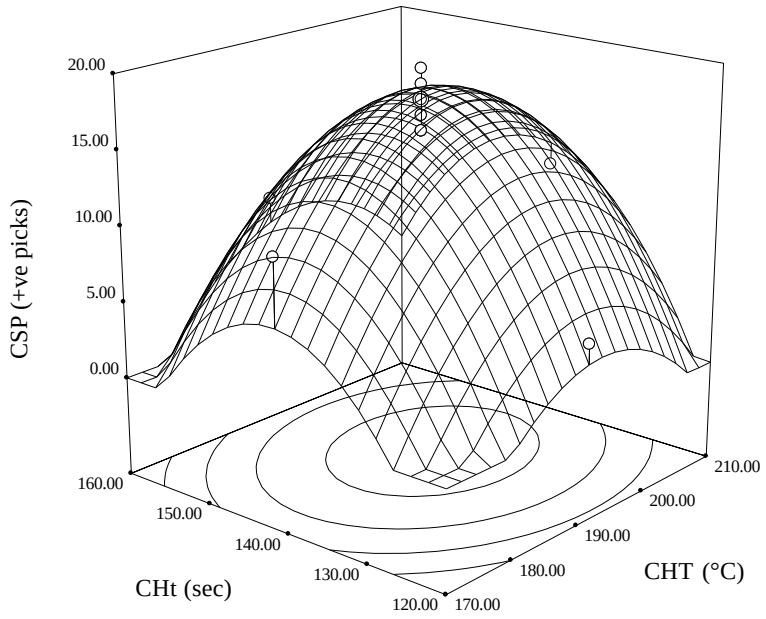


Fig. 4.2A: The contour and response surface plots showing the effect of CHT and CHt on crispiness for microwave puffing.

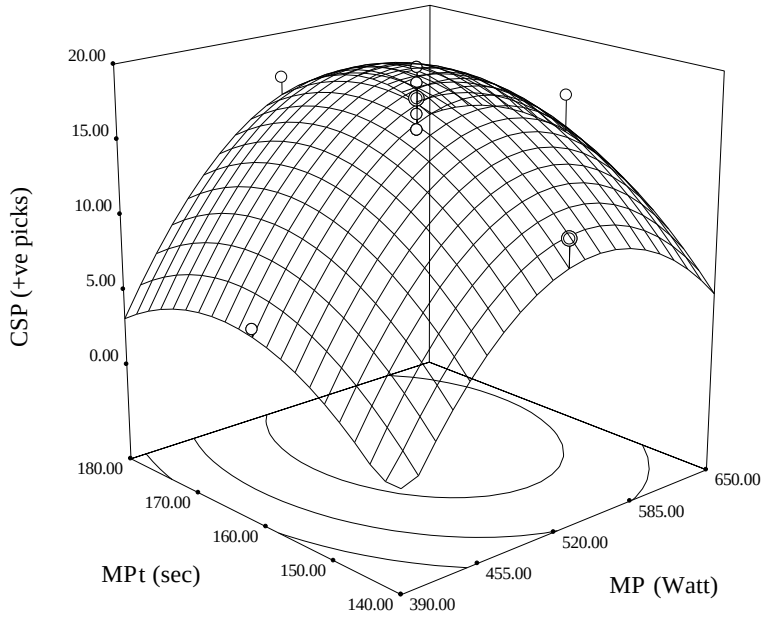


Fig. 4.2B: The contour and response surface plots showing the effect of MPand MPt on crispiness for microwave puffing.

moisture is slowly removed till 20-25 s time interval. The puffed product retained its soft texture due to relatively low rate of moisture removal during puffing period which resulted in marginal increase in crispness of product (Mazumder et al., 2007). As a result of this there was not considerable increase in crispness with corresponding increase in CHt.

Table 4.4: Analysis of variance (ANOVA), the effect of independent variables on moisture content, expansion ratio, crispness and hardness of composite millet flour based puffed product

Source Variation	df	F value				
		MC	HD	CSP	ER	CL
Model	14	21.725	2.199	8.231	84.134	2.447
CHT	1	20.588	5.621	10.062	277.83	0.401
CHt	1	20.468	0.489	3.758	31.774	5.332
MP	1	21.686	1.509	17.888	13.226	4.431
MPt	1	58.4002	0.305	8.975	76.179	0.714
CHT x CHt	1	60.833	4.103	0.186	4.320	0.196
CHT x MP	1	1.7323	0.308	1.165	55.106	0.076
CHT x MPt	1	0.7416	8.094	1.164	1.989	1.192
CHt x MP	1	2.747	0.059	0.000	2.430	2.222
CHt x MPt	1	0.0675	1.414	0.000	21.183	5.614
MP x MPt	1	29.986	0.941	0.000	5.642	0.270
CHT^2	1	0.000	0.000	21.304	218.74	3.049
CHt^2	1	0.000	0.000	47.285	59.207	11.558
MP^2	1	0.000	0.000	21.304	544.89	0.003
MPt^2	1	0.000	0.000	6.956	33.07	0.055
Lack of Fit	10	4.437^{NS}	1.740^{S}	2.519^{NS}	3.928^{NS}	2.203^{NS}
R^2		0.919	0.536	0.884	0.987	0.689
Adj R^2		0.877	0.292	0.777	0.975	0.416
Pred R^2		0.698	0.413	0.419	0.934	-0.497
Std. Dev.		0.0031	5.837	2.317	0.068	1.678
C.V. %		7.799	4.311	20.996	4.007	3.93

CHT-Convective heating temp (^{0}C), CHt-Convective heating time(sec), MP-Microwave Heating Power (% of total capacity), MPt-Microwave Puffing time (sec); ^{S}-Significant, ^{NS}- Non- significant

4.4.4 Effect of Various Process Parameters on Expansion Ratio (ER) During Microwave Puffing

The observations for expansion ratio with different combination of the process parameter were recorded as shown in Appendix-III and were analysed for regression analysis (Table 4.4). It varied from 1.125 and 2.167 within combination of variable studied. The quadratic model was fitted to the

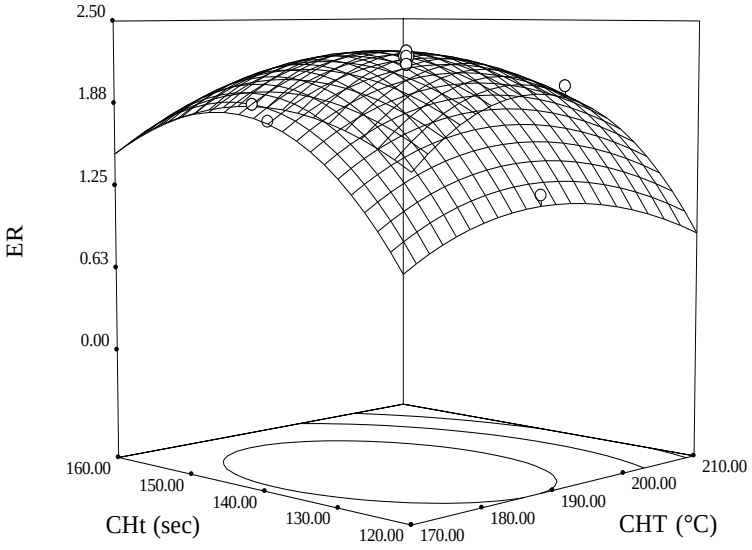


Fig. 4.3A : The contour and response surface plots showing the effect of CHT and CHt on expansion ratio for microwave puffing.

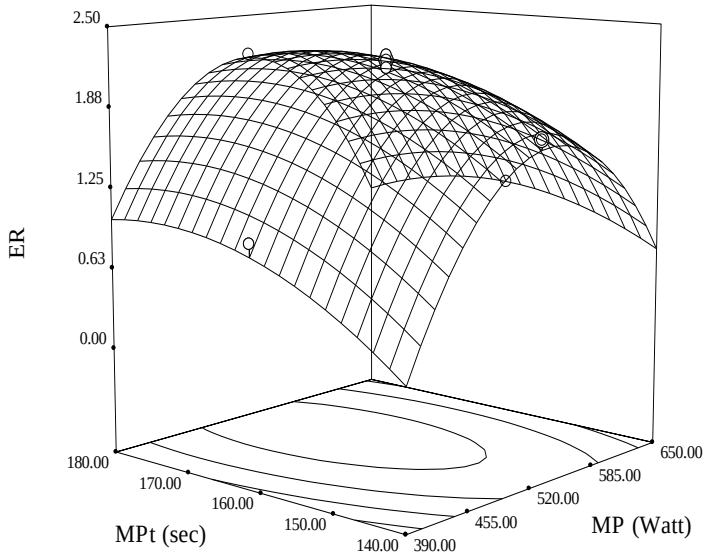


Fig. 4.3B : The contour and response surface plots showing the effect of MP and MPt on expansion ratio for microwave puffing

experimental data and statistical significance for linear and quadratic terms was calculated for ER as shown in Eq. (4.3). The R^2 value was found 0.98 showing good model fit. The Predicted R^2 of 0.93 is close to the Adjusted R^2 of 0.97. However, this model could be used to navigate the design space. The regression equation describing the effect of the process variables on expansion ratio of composite millet flour based RTE snack food in terms of actual level of variables are given as:

$$\begin{aligned} ER = -141.23 &+ 0.88 \times CHT + 0.19 \times CHt + 0.115 \times MP + 0.22 \times MPt \\ &- 0.00035 \times CHT \times CHt - 0.0002 \times CHT \times MP \\ &- 0.0002 \times CHt \times MPt + 4.04E - 05 \times CHt \times MP \\ &+ 0.001 \times CHt \times MPt - 6.2E - 05 \times MP \times MPt - 0.002 \times CHT^2 \\ &- 0.001 \times CHt^2 - 7.1E - 05 \times MP^2 - 0.0007 \times MPt^2 \ldots (4.3) \end{aligned}$$

It can be observed from ANOVA that microwave power (MP) was most significant parameter affecting the expansion ratio followed by convective heating temperature (CHT) at quadratic level. The R^2 value was calculated by a least square technique and found to be 0.98, showing good fit of model to the data. The lack of fit F-value was non-significant for the model obtained shown in Table 4.4, which indicates that the developed model was not adequate for predicting the response. The response surface and contour plots were generated for the fitted model (Eq. 4.3) as a function of two variables while keeping other two variables at their central values as shown in Fig. 4.3A and Fig. 4.3B.

It was observed that ER increased with increase in MP at all levels of Mt to reach to maxima and started decreasing when MP and Mt were increased above. Maximum volume of expansion of 2.212 obtained 520 W microwave powers for 160 s. This ER was similar to that obtained 2.16 for potato cubes (Mukherjee, 1997) and greater than 2.06 for barnyard millet puffed product (Jaybhaye and Srivastav, 2010) this is due to different in nature of product.

4.4.5 Effect of Various Process Parameters on Color During Microwave Puffing

The data recorded for Color (L-value) after each set of experiment shown in Appendix-III. It could be observed that the values of color (L-value) were ranged between 38.48 and 48.61. The quadratic model was fitted to the experimental data and statistical significance for linear and quadratic terms was calculated for color (L-value) as shown in Table 4.4. The R^2 value was calculated by a least square technique and found to be 0.69, showing good fit of model to the data. The model F-value of 2.45 implies that the model is significant. The lack of fit F-value was non-significant for the model obtained shown in Table 4.4 which indicates that the developed model was adequate for predicting the response. The response surface and contour plots were generated for the fitted model (Eq. 4.4) as a function of two variables while keeping other two variables at their central values as shown in Fig. 4.4A and Fig. 4.4B.

$$\begin{aligned} CL = {} & 537.71 - 3.19 \times CHT - 2..39 \times CHt - 0.24 \times MP + 0.56 \times MPt \\ & + 0.0018 \times CHT \times CHt + 0.0018 \times CHT \times MP \\ & + 0.0046 \times CHt \times MPt + 0.001 \times CHt \times MP - 0.01 \times CHt \times MPt \\ & + 0.006CHT^2 + 0.011CHt^2 + 4.07E - 06 \times MP^2 \\ & - 0.00075 \times MPt^2 \ldots (4.4) \end{aligned}$$

4.4.6 Optimization of Microwave puffing process for RTE snack foods

To perform this operation, Design-Expert program (Trial version 10.0.3) of the Stat-Ease software (2016), was used for simultaneous optimization of the multiple responses. The desired goals for each factor and response were chosen from the software generated ten optimum conditions of independent variables with the predicted values of responses which is shown in Table 4.5. From Table 4.6, solution no.1, having the maximum desirability value (0.69) was selected as the optimum conditions microwave puffing for developing composite millet flour based RTE snack foods.

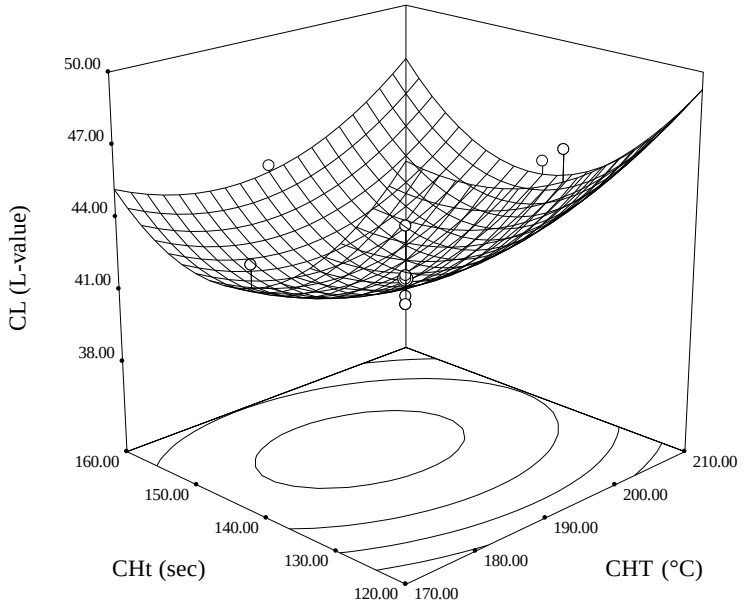


Fig. 4.4A: The contour and response surface plots showing the effect of CHT and CHt on color for microwave puffing.

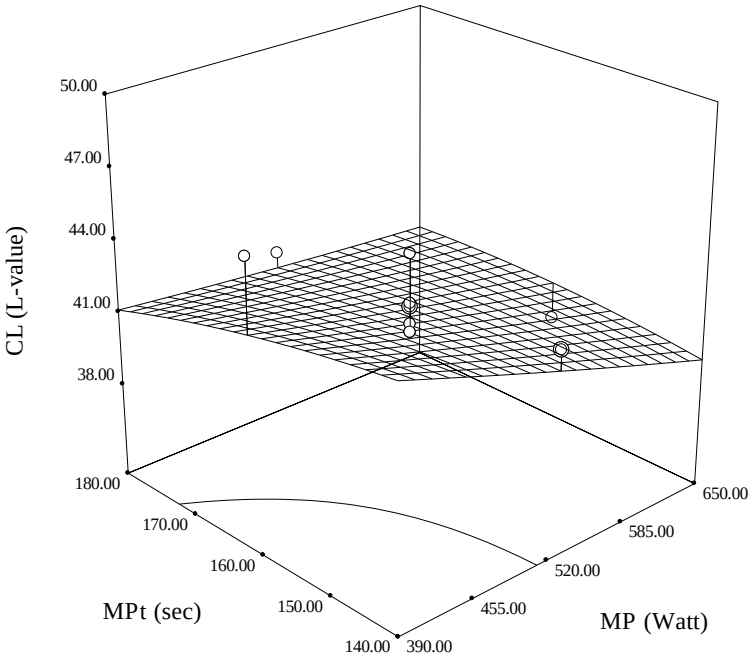


Fig. 4.4B: The contour and response surface plots showing the effect of CHT and CHt on color for microwave puffing.

Table 4.5: Optimization criteria for different process variables and responses for microwave puffed process for composite millet flour based RTE snack foods

Name	Goal	Lower Limit	Upper Limit
CHT, ^{o}C	is in range	170	210
CHt, s	is in range	120	160
MP W	is in range	390	650
MPt, s	is in range	140	180
MC (kg/kg dm)	Minimize	0.0219	0.0632
CSP	Maximize	4	20
ER	Maximize	1.01	2.267
C (L-value)	Maximize	38.48	48.61

Table 4.6: Solution generated by the software for microwave puffed process for composite millet flour based RTE snack foods

Sr. No.	CHT, ^{o}C	CHt, s	MP, W	MPt, s	MC, kg/kg dm	CSP, +ve picks	ER	C (L-value)	Desirability
1	195.95	132.02	513.60	173.07	0.0304	15.13	1.96	43.97	0.69*
2	195.96	132.03	513.57	173.10	0.0304	15.13	1.96	43.97	0.69
3	195.94	132.02	513.58	173.04	0.0304	15.13	1.96	43.97	0.69
4	195.94	131.98	513.66	173.09	0.0304	15.10	1.96	43.99	0.69

*Selected

The optimum values of process variables obtained by numerical optimization as follows (See Table 4.6)-

Convective heating temperature (CHT): 195.95 ℃ ~ 196 ℃

Convective heating time (CHt) : 132.02 s ~ 132 s

Microwave power (MP) : 513.60 W ~ 520 W

Microwave puffing time (MPt) : 173.07 s ~ 173 s

The optimum values of response parameters obtained by numerical optimization as follows (See Table 4.6)-

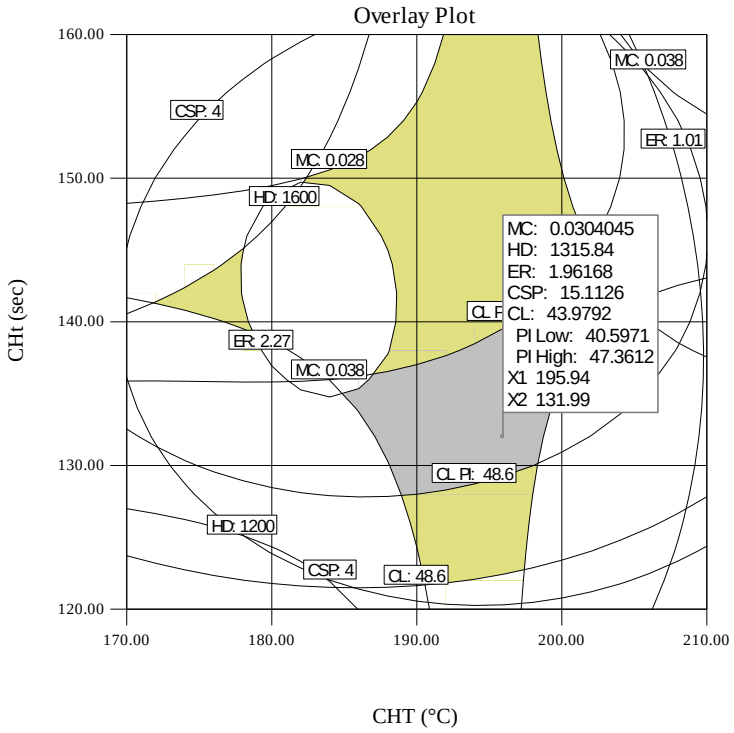


Fig.4.5A: Superimposed contours for MC, ER and CSP (+ve peaks) for microwave puffing of composite millet flour based RTE foods at varying CHT and CHt.

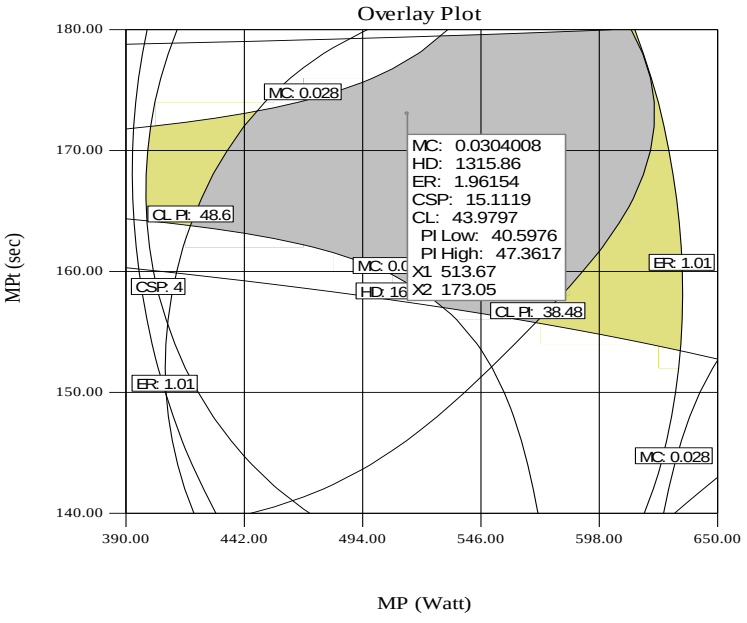


Fig.4.5B: Superimposed contours for MC, ER and CSP (+ve peaks) for microwave puffing of composite millet flour based RTE foods at varying MP and MPt.

Moisture content (MC) : 0.0304 kg/kg dm (3.04 % db)

Crispness (CSP) : 15.13 +ve picks

Expansion ratio (ER) : 1.96

Color (L-value) : 43.97

The superimposed contours of all responses for CHT and CHt (Fig. 4.5A) and MP and MPt (Fig. 4.5B) and their intersection zone for minimum MC (kg/kg dm), maximum ER, maximum C (L-value) and maximum CSP indicated the ranges of variables which could be considered as the optimum range for best product quality.

4.5 Optimization of the fortification level for incorporation of sprouted soybean in composite flour for preparing microwave puffed RTE snack foods

The fresh cold extrudate was prepared from composite millet flour at moisture content of 0.7024 kg/kg dm, adding sprouted soy paste at various levels upto 25 % as discussed in section 3.11. The incorporation of sprouted soybean was on dry matter basis. The changes in different physical quality parameters were as given in Table 4.7. Visual observations shown in Plate 4.2A and 4.2B.

4.5.1 Moisture content

Moisture present in sample is very important factor for preparation of any cold extrudate product. Microwave puffing is directly related to the moisture. The Table 4.7 shows that the significant decrease in moisture content was found as proportion of sprouted soy increases. The range of moisture content decreased from 0.0383 kg/kg dm to 0.0202 kg/kg dm) was obtained by varying the level of incorporation of sprouted soy paste.

4.5.2 Expansion ratio

In extrusion cooking of biopolymers, the viscoelastic material is forced through the die so that the sudden pressure drop causes part of water vaporize, giving an expanded porous structure (Sawant et al., 2013). The result of expansion ratio varied between 2.09 to 2.31 shown in Table 4.7.

The result of expansion ratio of RTE snack indicates that expansion ratio decreases with increase in level of pulses or protein. Protein affects expansion through their ability to effect water distribution in the matrix. Plate 4.2B clearly showed the effect of incorporation of 25 % sprouted soybean during preparation of RTE snack foods directly affected the expansion of product. Therefore, upto 20 % (db) of sprouted soybean fortification was possible. Similar result obtained by Deshpande and Poshadri (2011).

Table 4.7 Effect of fresh sprouted soy proportion on different quality parameters of microwave puffed composite millet flour based RTE snack food

Sr. No.	Fresh Sprouted Soy %	Moisture content (MC, % db)	Expansion Ratio (ER)	Hardness (HD, g)	Crispness (CSP, +ve picks)	Color		
						L	A	b
1	0	3.83^{a}	2.217^{a}	1344.95^{a}	17.333	45.363^{a}	2.983^{a}	6.07^{a}
2	5	2.84^{b}	2.231^{b}	1345.21^{a}	15.333	46.093^{a}	3.627^{a}	10.15^{b}
3	10	2.75^{c}	2.051^{c}	1225.84^{b}	14.667	53.237^{b}	3.897^{b}	9.90^{b}
4	15	2.67^{d}	2.133^{d}	1242.53^{c}	15.333	53.210^{b}	5.307^{c}	11.76^{c}
5	20	2.02^{e}	2.096^{e}	1232.64^{d}	20.667	56.153^{b}	3.620^{d}	11.10^{c}
F-cal		922.04	768.87	902.83	1.081^{NS}	11.253	16.437	7.08
CD (5%)		0.0647	0.00847	6.191	7.145	4.339	0.645	2.252

F-table (5%, 3.11; column wise values superscripted by similar letters are at par with each other

4.5.3 Hardness and Crispness

The hardness of RTE snack was determined by measuring the force required to break the product. The higher value of maximum peak force required in gram, which means the more force required to breakdown the sample, the higher the hardness of sample to fracture. The hardness of RTE snacks was significantly varied from 1225.84 g to 1345.21 g as shown in table 4.7. This variation was due to incorporation of sprouted soybean in millet flour. The value of hardness of snack food with 20 % incorporation of sprouted soybean was 1232.64 g which founds less as compared to hardness reported for biscuit and potato chips (3000 to 4000 g) by Khodke (2000). Nath (2006) reported hardness for HTST air puffed potato snack foods about 2000 g.

0 % incorporation

10 % incorporation

20% incorporation

5 % incorporation

15 % incorporation

Plate 4.2A:Effect of variation of incorporation of sprouted soybean on RTE snack food

Plate 4.2B: Effect of 25 % incorporation of sprouted soybean

Crispness was measured in terms of development of major positive peaks. Crispiness was varying from 14.67 to 20.67 as observed from Table 4.7. It was found that, no more significant variation observed during variation of sprouted soy fortification level.

4.5.4 Color

Color is an important quality parameter which directly related to the acceptability of any food product. Color changes can give information about the extent of browning reaction such as caramelization, milliard reaction during the heat process (IIo and Berghofer, 1999).

The color (L*) is an indication of brightness. The color value of the product ranges from 45.36 to 56.15. Table 4.7, it could be said that, the lightness to product increased with increase in sprouted soybean level, which gave good indication towards the acceptability of product. Another color parameter a*, indicates the redness of sample varied from 2.98 to 5.31. The yellowness value (b*) was ranged between 6.07 to 11.76 as shown in Table 4.7. The yellowness of extrudate during process was most induced by the non-enzymatic browning. All these differences could have been due to the share force generated during extrusion which accelerated the chemical reaction between amino acids and reducing sugars mallard reaction) takes place during process (Guy, 2001).

The overall results from Table 4.7, observed that though the expansion ratio decreased significantly as sprouted soybean incorporation level increased. In other hand, the desired decrease in moisture content and hardness, desired increase in color (L-value) was an advantageous. Also, observed that, the crispiness did not vary significantly with change in sprouted-soy proportion in composite millet flour used for preparation of microwave puffed snack while moisture content (MC), ER, color (L-value) and color (b-value) changed significantly.

From Plate 4.3B, the effect of incorporation of 25 % sprouted soybean in composite millet flour negatively affected the expansion of product. Therefore, incorporation of sprouted soybean was limited.

The conclusion drawn above discussion was that the incorporation of sprouted soybean upto 20 % (db) in composite millet flour was useful for preparation of RTE snack.

4.6 Study on mass transfer during microwave puffing process of sprouted soy fortified composite flour based ready-to-eat snack.

4.6.1 Effect of moisture content and puffing time on rate of moisture removal of RTE snack food

From fig. 4.6, it could be observed that moisture content of sample was continuously decreasing with time at 196 ℃ convective heating temperatures except during 30 to 70 s, where the moisture content remained almost constant, which corresponded to the drastic reduction in rate of moisture removal (Fig. 4.6). The convective heating air temperature throughout the puffing period had a great effect on puffing kinetics.

Close observation of the graphical representation of MC versus convective heating time at constant convective heating temperature 196 ℃ (Fig. 4.6) indicated some different phenomenon. At constant convective heating temp 196 ℃, the initial moisture content was 0.7012 kg/kg dm observed as to a lower upto 0.6012 kg/kg dm (with initial 30 s of puffing time) as shown in stage A. This indicated that there was surface moisture removed, leading to case hardening. The case hardening, subsequently, prevents further moisture removal from within the product. From level of moisture content of 0.6012 to 0.5671 kg/kg dm (during next 30 to 70 s of convective heating time) as shown in stage B. Further (after 70 s) decrease of moisture content causes for surface drying.

Therefore, at this stage microwave power supplied to product (Fig. 4.7) and variation of change in moisture content was found with increase in microwave puffing time. From Fig. 4.7, it could be observed that moisture contents of puffing samples were continuously decreasing with puffing time at all microwave power except initially upto 30 s at microwave power of 390 W to 650 W. The microwave power throughout the puffing period had a great effect on puffing

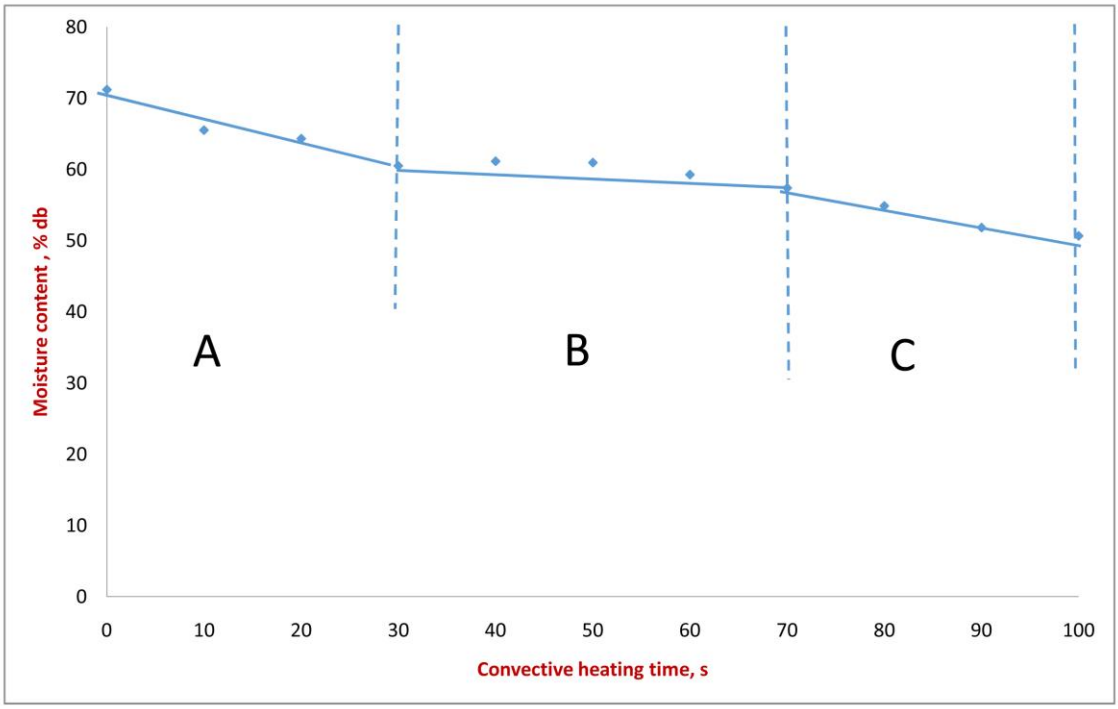


Fig. 4.6: Moisture removal during convective heating temperature

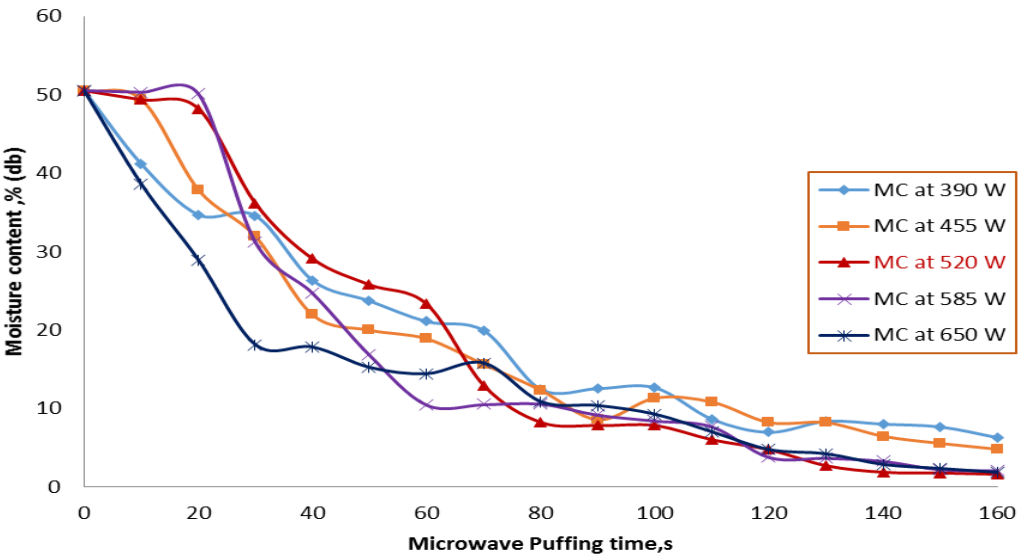


Fig. 4.7: Moisture removal with microwave puffing time of sprouted soy fortified RTE snack food at different microwave power

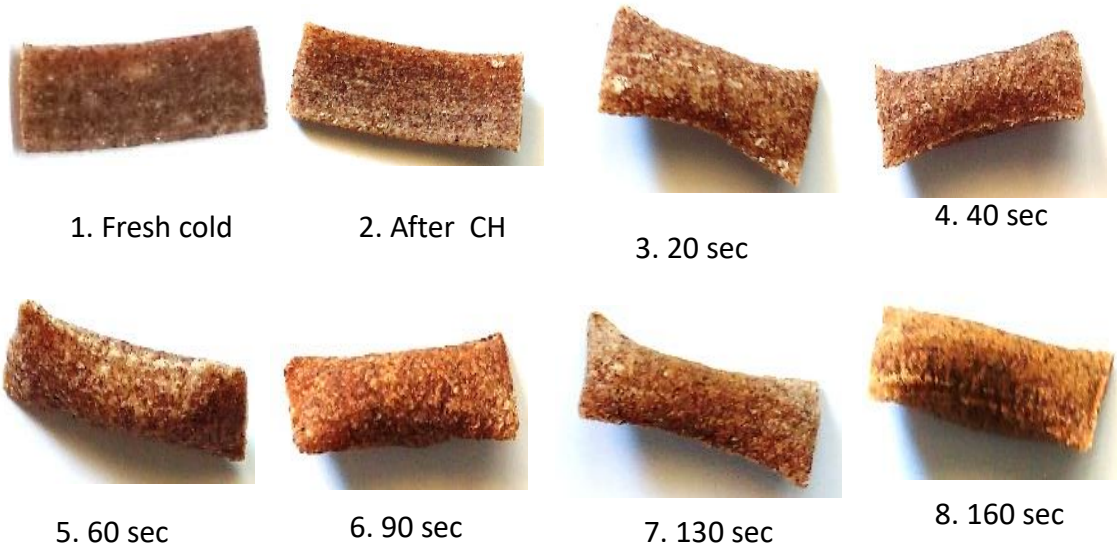


Plate 4.3A:Stage-wise development during microwave puffing of sprouted soy fortified composite flour based RTE snack food

Plate 4.3B: Caramelization over 170 s during microwave puffing

kinetics. The percent moisture removal reached its maximum values at higher power. The variation in moisture content during puffing snack foods were as recorded in Appendix- (IV).

During initial 15 s of microwave puffing time at microwave power 455 W, the moisture content of product remained almost constant. While at microwave power 520 W and 585 W, the moisture content of product remained unchanged upto 25 s.

From this, it is evident that the case hardening might have taken place by this time and the rate of heat transfer might have exceeded the rate of mass transfer (Chandrasekhar and Chattopadhyay, 1989). Further heating might have caused conversion of moisture, entrapped within product, into vapors, imparting puffing effect. After few seconds, once puffing is advanced, the vapours exerting pressure from within the expanding product might be helping to develop cracks in the puffed walls. Through these cracks, the vapours may start escaping indicating accelerated rate of moisture removal. Similar result was found by Pardeshi (2008).

The plate 4.3A shows variation in shape and size of product at each stage (i.e. 1. fresh product, 2. after convective heating, 3. after 20 s up to 160 s). From stage first, it can be seen that, puffing starts from centre. Due to continuous microwave heating, the vapours built up inside the product causing puffing and development of cracks along puffing wall. The further heating caused removal of vapours and expansion of product with over burning causes caramelization after 170 s of microwave puffing as shown in Plate 4.3B.

4.7 Study on bio-chemical analysis of optimally developed ready-to-eat snack foods, during process

Since the process for preparation of RTE snack foods from composite millet flour involved heat treatments at stage of steaming, convective heating, microwave puffing, it is necessary to verify the changes occurring during each set of process. Therefore, the various bio-chemical composition viz., fat, protein, ash, carbohydrate and moisture content were determined at each stage of process (as given in section 3.4.1) for the product.

4.7.1 Change in bio-chemical composition of composite flour based product during process

The initial moisture content in composite flour mixture was 9.67 % db. From table 4.8, moisture content was observed, to be reduced significantly during preparation of RTE snacks from 74.42 to 3.68 % db. However, no significant change in protein content of product during steaming, convective heating and microwave puffing was observed. The fat content was more significantly reduced from 4.98 to 1.25 % db. Ash content increased during process, it might due to incorporation of salt in mixture. The significant variation in carbohydrate (including fibers) was seen during preparation of fresh cold extrudate. According to Giami (1993), the heat treated and autoclaved (121 ℃, 105 kPa, 15 min) cowpea samples showed 5% reduction in protein content. The reduction in protein content may be accredited to denaturation of proteins (Manay and Shadakharswamy, 2004). The calorific value of final RTE product was calculated to be 393.64 kcal/100 g.

Table 4.8 Composition of product at various stages during process of preparation of microwave puffed composite millet flour based RTE snack food

Stage of product	Moisture content (MC, %db)	Protein %,db	Fat %,db	Ash %,db	Carbohydrates+ fiber%, db*	Energy kcal/ 100g product
Composite flour	09.67^{a}	12.45	4.98^{a}	2.11^{a}	80.45	420.23
After steaming	74.42^{b}	11.58	2.94^{b}	3.42^{b}	82.06	404.79
After convective heating	60.36^{c}	11.14	2.21^{b}	3.66^{b}	82.98	400.18
After microwave puffing	03.82^{d}	09.55	1.25^{c}	4.10^{b}	85.09	393.64
CD (5%)	2.02	NS	0.835	0.678	NS	
*by difference The column wise values superscripted by similar letters are at par with each other						

4.7.2 Change in biochemical composition of sprouted soy fortified composite millet flour RTE snack foods

From table 4.9, moisture content was observed to reduce significantly during preparation of cold extrudate. The initial moisture content in sprouted soy fortified composite flour mixture was 70.12 % (db). It was reduced upto 2.06 % (db) in final product. Due to sprouted soy protein fortification, the increase in protein content was observed in fresh cold extrudate and was varied from 17.97 to 15.82 %. The fat content was more significantly reduced from 4.51 to 1.13 % (db). Ash content increased during process. It might be due addition of salt in mixture. Less significant change in carbohydrate content was observed during the product preparation. According to Giami (1993), the heat treated and autoclaved (121 ℃, 105 kPa, 15 min) cowpea samples showed 5% reduction in protein content. The reduction in protein content may be accredited to denaturation of proteins (Manay and Shadakharswamy, 2004). The energy value was in final product 391.99 kcal/100 g.

Table 4.9: Composition of product at various stages during process of preparation of sprouted soy fortified composite flour microwave puffed RTE snack food

Stage of product	Moisture content (MC, %db)	Protein %,db	Fat %,db	Ash %,db	Carbohydrates + fiber% (db)*	Energy kcal/ 100g product
Sprouted soy Composite flour mixture	70.12^{a}	17.97^{a}	4.51^{a}	2.41^{a}	75.11^{a}	416.63
After steaming	74.24^{b}	16.91^{b}	4.58^{b}	2.29^{b}	75.81^{b}	398.46
After convective heating	56.75^{c}	15.66^{c}	1.70^{c}	4.71^{c}	77.93^{c}	393.41
After microwave puffing	02.06^{d}	15.82^{d}	1.13^{d}	4.34^{d}	78.69^{d}	391.99
CD (5%)	0.32	0.165	0.0285	0.0213	0.0143	--
						--
*by difference The column wise values superscripted by similar letters are at par with each other						

4.8. Sensory evaluation

The sensory evaluation of the microwave puffed sprouted soy fortified composite flour (with and without addition of spices) compared to commercially available similar RTE snack was carried out following 9-point hedonic scale as per BIS (1971). The sensory score given to respective optimally prepared product and commercially available similar product is given Appendix-IV. The score given for various sensory quality attributes by judges were statistically analysed using Analysis of variance (Montgomery, 2001). The quality attributes considered for sensory evaluation were color, flavor, texture and overall acceptability (OAA). Six samples as coded in table 4.10 were served to the judges and the judges were asked to evaluated those sample as guided as shown in score sheet provided (Appendix-V).

Table 4.10 Encoding of the product considered for sensory evaluation

Product Code	Name of product
01	Microwave puffed composite millet flour based RTE snack food
02	Microwave puffed composite millet flour based RTE food with incorporation of spices
03	Microwave puffed 20 % sprouted soy fortified composite millet flour based RTE food with incorporation of spices
04	Microwave puffed 20 % sprouted soy fortified composite millet flour based RTE snack food with incorporated spices applied vinegar
05	Microwave puffed 20 % sprouted soy fortified composite millet flour based RTE snack food with applied vinegar and spices
06	Commercially available RTE food

The data on sensory evaluation was obtained as given in Appendix-VI. This data was statistically analysed using analysis of variance. The results are given in Table 4.11. From analysis of variance, it could be seen that the coefficient of variance amongst the different judges was 14.86 %. The data on sensory evaluation was obtained as given in Appendix-VI. This data was statistically analysed using analysis of variance. The results are given in Table

4.11. From analysis of variance, it could be seen that the coefficient of variance amongst the different judges was 14.86 %

Table 4.11 ANOVA (Analysis of variance) of sensory evaluation of different products

Product code	01	02	03	04	05	06
Factor Means	7.125^{ab*}	6.675^{a}	6.800^{a}	$7.325^{b\$}$	7.600^{bc}	7.975

*The raw wise values superscripted by similar letters are at par with each other, F cal=8.29(Sig.), CD (5%)=0.487, CV= 14.86%, $ - selected to ease in application of spices.

The samples coded as 01, 02 and 03 were at par with each other and their quality attributes indicted that these three products were least liked by the judges. The product code 04 and 05 are at par with each other, but incorporation of spices in product code 04 was easy than applied spices in product code 05 for puffed product. Therefore, product code 04 indicated that 20 % incorporation of sprouted soybean with incorporation of spices, microwave puffed RTE snack may acquire higher liking by the consumers. The nutritional value of final product is given in Table 4.12.

Table 4.12: Nutritional composition per 100g of sprouted soy fortified composite millet flour based RTE snack food

Sr. No.	Parameter	Nutritional value
1	Protein (g/100 g)	15.82
2	Fat (g/100 g)	1.13
3	Ash (g/100 g)	4.34
4	Carbohydrates including fibres (g/100 g)	78.69
5	Energy (kcal/kg)	393.64
6	Total Antioxidant activity (µg/g)	1016.50
7	Phenols (mg/100 g)	66.89
8	Trypsin Inhibitor Activity	Not detected
9	Phytic acid (mg/100 g)	241.84
10	Tannin (mg/100 g)	100.00
11	Calcium (mg/100 g)	145.50
12	Iron (mg/100 g)	13.99
13	Sodium (mg/100 g)	577.60
14	Potassium (mg/100 g)	581.08

Plate 4.4: Sprouted soy fortified microwave puffed composite millet flour based RTE snack food

4.9 Study on shelf life of optimally developed ready-to-eat snack foods

This section deals with the changes observed in the product during the storage studies under relative humidity, 95 % at 40 ℃. As already discussed in the section 3.15, the product was stored in two types of packaging material (HDPE and MP) for above conditions during storage studies.

4.9.1 Properties of packaging materials

The cumulative moisture gain with time by silica gel kept in two pouches (HDPE and MP) at 40 ± 2 ℃ temperatures and 95 ± 1 % relative humidity measured as discussed in section 3.15.2. From the slope of respective curves, the WVTR were determined and found to be as shown in Table 4.13.

Table 4.13 Water vapor transmission rate of packaging material

Sr. No.	Packaging Material	Thickness (microns)	WVTR (kg water/day m^2)	Permeability (kg water/day m^2 Pa)
1	HDPE	100	0.00264	3.63 E-06
2	MP	40	0.00406	1.07 E-05

4.9.2 Sorption isotherm of the optimally developed RTE snack foods

Sorption isotherms of RTE snack foods at 45 ± 1 ℃ and 95 % RH, showing the variation of moisture content of the products with water activity (a_w) are given in fig. 4.8. The water activity value of the finished products with 0.0256 kg/kg dm moisture content for RTE snack was found to be 0.192 at the said temperature (Appendix-VII). Moisture content increased slowly with increase in water activity until the water activity values of about 0.564 for sprouted soy fortified composite millet flour based RTE snack foods, after which rapid increase in moisture content was observed. Thus, it was concluded from the fig. 4.8 that the water activity values of about 0.564 could be taken as the critical water activity with critical moisture content 0.105 kg/kg dm, values of sprouted soy fortified composite millet flour based RTE snack foods, beyond which the products would lose crispness. Similar phenomenon was observed by Katz and Labuza (1981) and they reported that the critical water activity values for crisp product ranged between 0.35 and 0.50. Quast and Karel, (1972) reported critical

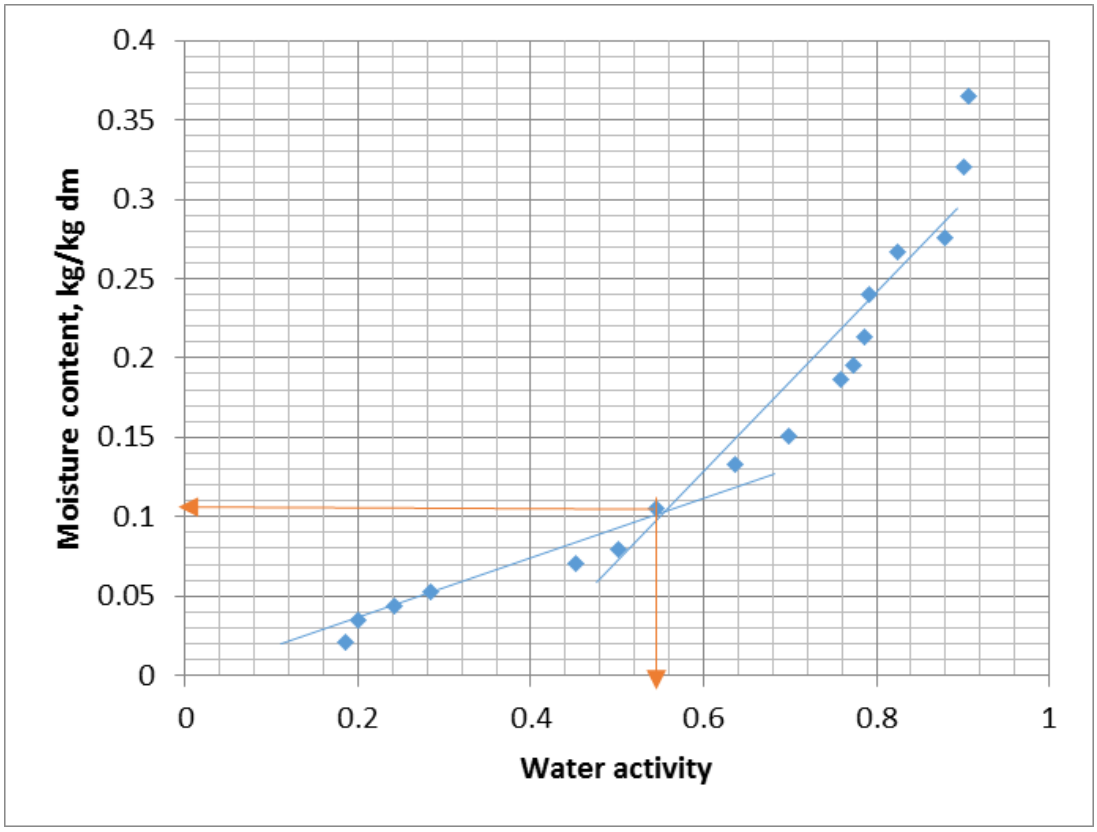


Fig. 4.8: Water activity of RTE snack foods during storage

water activity values for popcorn and potato chips as 0.50 and 0.40, respectively. Khodke (2001) reported critical water activity of 0.48 for dehydrated RTE potato cubes. Nath (2006) reported about 0.47 and 0.45 as the critical water activity values of RTE potato and RTE potato-soy snack foods, respectively.

Crispness, which was one of the main criteria for RTE snack foods for the acceptability of product. Water activity of the product was considered as an index of shelf life of crispy materials as reported by earlier researchers (Katz and Labuza, 1981).

4.9.3 Self life of sprouted-soy fortified RTE snacks:

Table 4.14: Predicted shelf life of microwave puffed sprouted soy fortified composite millet flour based RTE snack food

Temp. (°C)	Relative humidity (%)	Packaging Material	Observed shelf life (days)	Predicted shelf life (days)
30	65	HDPE	-	91
30	65	MP	-	156
45	95	HDPE	22	24
45	95	MP	38	40

At very high humidity (95 %) the snack foods lost its shelf life within 24 days in HDPE and 40 days in MP. Appendix-VIII showed the the variation of moisture content during storage at temperature 45 ℃ and relative humidity 95 %. Thus, from Table 4.14, it could be concluded that the product if stored in MP package at moderate RH (65 %) and ambient temperature of 30 ℃, considerably long shelf life of 156 days (i.e. 5 months) in case of sprouted soy fortified composite flour based RTE snack foods.

CHAPTER V

SUMMARY AND CONCLUSIONS

The importance of breakfast cereal is gaining significance in an era of changing life-style, rapid urbanization, convenience and above all, a health-conscious society. The convenience as ready-to-eat (RTE) foods is also becoming popular among the people. Extrusion cooking is one of the very popular contemporary food processing technologies and is largely followed for corn and rice but the millets could also be extruded to prepare ready-to-eat (RTE) products. However, the balanced and sufficient nutrition content of available ready-to-eat foods is major issue of verification. Despite their beneficial nutritional properties and tolerance for adverse growing conditions, millet consumption has been less compared to major cereals such as rice, wheat and corn. Millet products from 100 % millet flour are rarely manufactured. Among millets, small millets have been most neglected. There is a need to increase awareness about the superior nutritional quality of millets and make them one of the important commodities in our food basket.

Therefore, the way to prepare composite dough from minor millet grains and fortifying the same with sprouted soybeans is thought to be taken up for preparing RTE foods by following microwave puffing technique. the present study has been undertaken with the following specific objectives

1. Study on biochemical profile of soybean during process of sprouting.
2. Optimization of microwave puffing process for preparing ready-to-eat snack from millet flours.
3. Optimization the fortification level for incorporation of sprouted soybean in millet flour for preparing microwave puffed ready-to-eat snack.
4. Study on mass transfer during microwave puffing process of sprouted soy fortified composite flour based ready-to-eat snack.
5. Study on biochemical analysis of optimally developed ready-to–eat snack during process.
6. Study on shelf life of optimally developed ready-to-eat snack.

The refined finger millet flour, foxtail millet flour, pearl millet flour and barnyard millet flour were the primary raw material for preparation of snack foods in the present investigation. Sprouted soybean used as the secondary raw material to enrich the protein content of the final product. The minor millets were purchased from local market. Soybean ***(Glycine max Cv.JS-335)*** was procured from the Seed Technology Research Unit, PDKV, Akola. This variety has good germination, high yield and resistant to major diseases and pest.

The sprouting of soybeans was conducted with respect to its soaking time for four hours in clean water and subsequently rinsing at an interval of 6 h for 6 to 7 times would be optimum to attain optimal sprouting of soybean (Tayade, 2010; Pardeshi and Tayade, 2013).

Proximate compositions and nutritional properties of initial raw material namely, moisture content, protein, fat, carbohydrate (including fibres), ash and energy value etc. required for the present investigation were determined.

Best composites flour combination is decided on the basis of micronutrient rich millets-

Composite Flour with proportion-

1. Finger millet flour (40)
2. Foxtail millet flour (30)
3. Pearl millet flour (20)
4. Barnyard millet flour (10)

The composite flour was taken in the ratio of Finger millet: Foxtail millet: Peral Millet: Barnyard millet :: 40:30:20:10 respectively and two gram per 100 gram of flour salt was added for taste. The composite flour was mixed together with addition of 55 mL water for cold extrusion (Pawar et al., 2014) The above cold extradate was subjected to steaming for specific time so as to impart gelatinization effect. These cold extrudates were steamed for 15 min (Pardeshi, 2008) at 1 kg/cm^2 in kitchen pressure cooker. The prepared mixture of basic ingredients was kneaded for 10 min to obtain granular mixture by using Dolly Mini P3 Pasta Machine (LaMonferrina Make). Appearance of uniform smaller size granules indicates the completion of the kneading process. After the process, the samples were extruded in the pasta machine using rectangular shape die.

The process variables considered were convective heating temperature (170-210 ℃), convective heating time (120-140 s), microwave power (390-650 W), microwave heating time (140-180 s) on the basis of preliminary trials. The experimental design was applied after selection of the ranges. Thirty experiments were performed according to a second order central composite rotatable design (CCRD) with four variables and five levels of each variable. Experiments were randomized in order to minimize the effects of unexplained variability in the observed responses due to extraneous factors. The centroid point in the design was repeated six times to calculate the reproducibility of the method (Montgomery, 2001).

Microwave puffing experiments were conducted according to the CCRD design (Table 3.3) and RSM was applied to the experimental data using a commercial statistical package, Design Expert – trial version 10.0.3 (Stat Ease, 2016). The relative effect of the process variables (convective heating temperature, convective heating time, microwave power, microwave heating time) on the responses was studied and the microwave puffing process was optimized in order to get best quality microwave puffed composite millet flour based ready-to-eat snack food. The responses studied were final moisture content (MC, kg/kg dm), expansion ratio (ER), hardness (HD, g), crispness (CSP, no. of +ve peaks) and sensory color score (CL).

The process parameters for microwave puffing of composite flour based RTE snack foods were optimized for minimum final moisture content (kg/kg dm), maximum expansion ratio, maximum color (L-value), maximum hardness (g) and maximum crispness (+ve peaks).

Using these optimized process conditions, sprouted soy percentage was varied (5 %, 10 %, 15 %, 20 % and 25 %) in composite minor millet flour to prepare optimally soy fortified composite minor millet flour-based snack foods. The responses were measured final moisture content (MC, kg/kg dm), expansion ratio (ER), color (L, a and b-value), hardness (HD) and crispness (CSP) and replicated thrice. The ANOVA (analysis of variance) was used for statistical analysis of data (Montgomery, 2001). Biochemical analysis of optimally developed product was conducted.

The nutritional composition of the optimally prepared samples at various stages i.e. composite flour, after steaming, convective heating and microwave puffed snack food were measured by standard analytical procedures.

The sensory evaluation of final products was carried out by a nine-point hedonic scale (BIS, 1971) was employed for all the attributes evaluated where 9 denoted "liked extremely" and 1 indicated "disliked extremely". The data on the sensory attributes like taste, flavor, color, texture and overall acceptability were analyzed.

The mass transfer study of final product was carried out on drying (if moisture removal during puffing is resembled to that in drying), is generally accepted to be the main mechanism during the transport of moisture to the surface to be evaporated.

A storage study was conducted on the final products prepared by optimized process conditions at 40 ℃ and 95 % relative humidity temperatures and packaging materials. Metalized polyester and high-density polyethylene used for storage studies, as these materials are known to be fairly good moisture and oxygen resistant and are being used commercially for packaging of crispy snack foods (Dhumal, 2010). The variation in moisture content and water activity (aw) were studied during storage.

The data obtained during the course of investigation were analysed and results are summarized below;

During biochemical analysis of soybean, sprouts was found to be increased protein content from 38.58 % to 42.25 % (db), fat content reduced from 19.98 to 16.01 % db. Non-significantly change in ash content 5.13.34 % db. The calorific value of sprouted soybean was calculated to be 462.68 kcal/100 g. The main anti-nutritional factor present in soybean seed was trypsin inhibitor, which was highly reduced from 4.43 mg/g to 0.205 mg/g (i.e. only 5 % inhibition present in seed after sprouting plus heating at 50 ℃), The reduction of about 88 % of non-digestible oligosaccharides (Raffinose family) dispersed after 48 h rinsing of soybean. In anti-oxidants, phenols were found

to be 135.24 mg/100 g, total anti-oxidant activity was 1170.84 µg/g in sprouted soybean (48 h rinsing).

The cold extrudate prepared from refined composite millet flour was steamed and puffed in microwave oven as mentioned above. The variation in moisture content, MC (kg/kg dm), expansion ratio (ER), color (L-value), Hardness (HD, g) and crispness (CSP, +ve peaks) of puffed product after puffing with respect to various process parameters viz., convective heating temperature (CHT, ℃), convective heating time (CHt, s), microwave power (MP, W), microwave puffing time (MPt, s). However, HD was not indicating non-significant lack of fit with steaming and puffing variables, therefore it was not considered for optimization purpose.

The optimum values of process variables obtained by numerical optimization as follows-

Convective heating temperature (CHT) : 196 ℃

Convective heating time (CHt) : 132 s

Microwave power (MP) : 520 W

Microwave puffing time (MPt) : 173 s

The optimum values of response parameters obtained by numerical optimization as follows-

Moisture content (MC) : 0.0304 kg/kg dm (3.04%, db)

Crispness (CSP) : 15.13 +ve picks

Expansion ratio (ER) : 1.96

Color (L-value) : 43.97

From above optimized process parameters, the fresh cold extrudate was prepared from composite millet flour with addition of sprouted soy paste at various levels upto 20 % (at moisture content of 0.7024 kg/kg dm). The results of this study showed that incorporation of sprouted soybean and composited millet flour can be effectively used to produce RTE extruded

snacks by extrusion cooking upto the 20 % of sprouted soybean not only improved the nutrient content of the snacks also increases the overall acceptability. The microwave puffed product at the optimal process condition having average moisture content of 0.0202 kg/kg dm, hardness 1232.64 g, crispness 20.67 (+ve peaks) and expansion ratio 2.096 and color (L, a and b value) found to be 56.15, 3.62 and 11.10, respectively.

At constant convective heating temp 196 ℃, the moisture content was observed 0.7012 kg/kg dm which decrease moisture content up to 0.6012 kg/kg dm with initial 30 s time as shown in stage A. This indicated that there was surface moisture removed, leading to case hardening. The case hardening, subsequently, prevents further moisture removal from within the product. From level of moisture content of 0.6012 to 0.5671 kg/kg dm (during next 30 to 70 s of convective heating time) as shown in stage B. Further, (after 70 s) decrease of moisture content causes for surface drying i.e. case hardening formed on surface of product.

At microwave power 455 W, initial 15 s of microwave puffing the moisture content of product remained almost constant. While at microwave power 520 W and 585 W, the moisture content of product remains unchanged upto 25 s. Therefore, it is seen that, microwave heating at 520 W for 170 s cases the phase conversion of entrapped moisture into vapours for 20-25 s which build up sufficient pressure so as to impart puffing effect upto 70 s and next heat causes backing and roasting of final product uotp 160 s only.

The various bio-chemical composition viz., fat, protein, ash, carbohydrate and moisture content were determined at each stage of process for sprouted soy fortified composite flour based RTE snack food products. The moisture content during process decreased significantly and finished product moisture content was found to be 2.06 % (db). Protein and fat reduced significantly during each stage of process and final values found to be 15.82 % and 1.13 % (db), respectively. Energy value of sprouted soy fortified RTE snack was 391.99 kcal/100 g of product.

The microwave puffed sprouted soy fortified composite millet flour based RTE snack food could be stored in Metallic polyester (40 micron)

package at moderate RH (65 %) and ambient temperature of 30 ℃, for considerably long shelf life of 156 days i.e. 5 months.

Conclusions

1. During sprouting process of soybean, the protein content increased from 38.58 to 42.25 % (db) and fat content reduced from 19.98 to 16.01 % (db) whereas there was non-significant change in ash (i.e. minerals) content. The calorific value of sprouted soybean was calculated to be 462.68 kcal/100 g.
2. The main anti-nutritional factor present in soybean seed was trypsin inhibitor, which was highly reduced from 4.43 mg/g to 0.205 mg/g (i.e. only 5 % inhibition present in seed after sprouting and heating at 50 ℃),
3. The reduction of about 88 % of non-digestible oligosaccharides (Raffinose family) disappeared after 48h rinsing of soybean.
4. In anti-oxidants, phenols were found to be 135.24 mg/100 g, total anti-oxidant activity was 1170.84 µg/g in sprouted soybean (48 h rinsing).
5. The optimal conditions of composite millet flour-based microwave puffing of the steamed cold extruded could be conducted by convective heating temperature at 196 ℃ for 132 s followed by microwave power of 520 W for 173 s. The microwave puffed product at the optimal process condition was having average moisture content of 0.0304 kg/kg dm, crispness 15.13 (+ve peaks) and expansion ratio 1.96 and colour (L-value) found to be 43.97.
6. The optimal level of fresh sprouted soybean fortification was found to be 20 g dm of sprouted soy/100 g dm of composite flour during RTE snack food preparation.
7. Biochemical analysis optimally developed sprouted soy-fortified RTE snack food was found to be rich in protein content 15.82 % (db), with very less amount of fat content 1.13 % (db) and higher amount of ash content 4.34 % (db) i.e. minerals.
8. No trypsin inhibitor activity detected after microwave puffing of sprouted soy fortified composite millet flour based RTE snack food.

9. During convective heating at 196 ℃, first 90 s causes surface moisture removal and imparts case hardening. Further microwave heating at 520 W for 170 s cases the phase conversion of entrapped moisture into vapours for 20-25 s which build up sufficient pressure so as to impart puffing effect upto 70 s and next heat causes backing and roasting of final product uotp 160 s only.
10. The microwave puffed sprouted soy fortified composite millet flour based RTE snack food could be stored in MP (40 microns) package at moderate RH (65 %) and ambient temp of 30 ℃ for considerably long shelf life i. e. 5 months.

CHAPTER VI

IMPLICATIONS

The present study was carried out for analysis of biochemical profile process of soybean during sprouting and development of composite millet flour based RTE snack food using microwave puffing.

During this study, the decrease in main antinutritional factors such as trypsin inhibitor activity and non-digestible oligosaccharides (Raffinose family) found to safe level.

The process was optimized for preparation of composite millet flour based RTE snack and fortified with sprouted soybean.

It was found the mass transfer study is most important for preparation of any RTE snack food, which will determine the accuracy about moisture level required for puffing.

Hence, the product prepared from fresh sprouted soy fortified composite millet flour based RTE snack food is safe for consumption.

Future Suggestion

From this research work, it was proved that the sprouted soybeans are nutritionally beneficial for protein fortification. But incorporation of fresh sprout soybean is more difficult due to stickiness of seed coat which was not remove easily. Therefore, dried sprouted soy flour will be useful for incorporation of and preparation of RTE food.

CHAPTER VII

LITERATURE CITED

Ahmad S and Pathak DK (2000). Nutritional changes in soybean during germination. Journal of Food Science and Technology, 37(6):665-666.

Ali N, Gandhi AP and Ojha TP (1988). Soybean processing and utilization in India. Central Institute of Agricultural Engineering, Nabi Bagh, Berasia road, Bhopal-462 018, India. Pp: 293.

AACC (1985). Approved Methods of the American Association of Cereal Chemists. Method 71-10, approved November 1973. The Association: St. Paul, MN.

American Soybean Association (2004). United Soybean Board. "Soy and Health". A review of the 3rd International Symposium on the role of soy in preventing and treating chronic disease, October 31, 1999 in Washington DC, USA.

Angioloni A and Collar C (2012). Suitability of oat, millet and sorghum in bread making. Food Bioprocess Technology. DOI:10.1007/s11947-012-0786-9.

Anonymous (2013). Pocket book on Agricultural Statistics. Government of India, Ministry of Agriculture, Department of Agriculture and Co-operation, Direction of Economics and Statistics, New Delhi.

Anonymous (2014). Standard Test Method to Qualify Single-Use Foodservice Packaging for Use in Microwave Ovens Method Revision: #1 – Feb/07. Determination of Microwave Power Output According to IEC 60705.

Anonymous (2015a). Millets-future of food and farming. Millet Network of India, Deccan Development Society - FIAN, India

Anonymous (2015b). Millet booklet- "Millets in your meal" Issued in Public interest by National Bank for Agriculture and Rural Development.

Antony U, Sripriya G and Chandra TS (1996). Effect of fermentation on the primary nutrients in finger millet (*Eleusine coracana*). Journal of Agriculture and Food Chemistry, 44:2616-2618.

Anuradha DD, Kulkarni SS, Sahoo AK and Dandge PB (2010). Effect of supplementation of malted ragi flour on the nutritional and sensorial quality characteristics of cake. Advance Journal of Food Science and Technology, 2(1):67-71.

AOAC (1975). Official methods of analysis (12th Ed.). Washington, DC: Association of Official Analytical Chemists (AOAC).

AOAC (1984). Official methods of analysis of the Association of Official Analytical Chemists (14th ed.), Washington, DC.

AOAC (2005). Official methods of analysis of the Association of Official Analytical Chemists (18th ed.), Washington, DC.

AACC (1983). Approved Methods of the American Association of Cereal Chemists. 8th ed. Method 44-15A, St. Paul, MN.

Arun Kumar TV, Samuel VK, Jha SK and Sinha JP (2015). Twin screw extrusion of sorghum and soya blends: A response surface analysis. Journal of Agriculture Science and Technology, 17:649-662.

Artz WE, Warren C and Villota R (1990). Twine screw extrusion modification of a corn fiber and corn starch extruded blend. Journal Food Science, 55(3): 746-750, 754.

Arya SS (1992). Convenience foods-emerging scenario. Indian Food Industry, 11(4):31-41.

Asp NG (1996). Dietary Carbohydrate: Classification by Chemistry and Physiology, Journal of Food Chemistry, 7:9-14.

Awasthi I, Pornoor S, Tripathi M and Tripathi V (2012). Development of soy fortified high protein and high calorie supplementary biscuits. Indian Journal of Science and Research, 3(1):51-58.

Babar OA (2011) Development of continuous hot air puffing system. Unpublished M. Tech. Thesis. Dept. of Agricultural Process Engineering, Dr. PDKV, Akola (MS).

Baladhandayutham S, Thangavelu V and Ezhumalai S (2009). Optimization of process variables using Response Surface Methodology (RSM) in the solid-state fermentative production of pectinase by *Aspergillus awamori.* Asian Journal of Food and Agro-Industry,2(3):302-314.

Balasubramanian S, Singh KK, Patil RT and Onkar KK (2011). Quality evaluation of millet-soy blended extrudates formulated through linear programming. Journal of Food Science and Technology. DOI:10.1007/s13197-011-0297-0

Bates RP and Mathews (1975). Ascorbic acid and β-carotene in soybeans as influenced by maturity, sprouting, processing, and storage. Department of Food Science, University of Florida, IFAS Gainesvillie. pp:266-272.

Bergman CJ, Gualberto DG and Weber CW (1994). Development of a High-Temperation-Dried soft wheat pasta supplemented with cowpea (*Vigna unguiculata* (L.) walp). Cooking quality, colour and sensory evaluation. American Association of Cereal Chemistry, 71(6):523-527.

Bhashyam MK (1982). Structure of rice grain in relation to technological properties, Unpublished Ph.D. thesis, University of Mysore. India.

Bhat KK and Bhattacharya S (2001). Deep fat frying characteristics of chickpea flour suspensions. International Journal of Food Science and Technology, 36(5):499–507.

Bhat KK and Bhattacharya S (2001). Deep fat frying characteristics of chickpea flour suspensions. International Journal of Food Science and Technology, 36(5):499–507.

Bhole SN (1992). Studies on the development of cereal-pulses based convenience food. Unpublished Ph.D. thesis, PHTC, IIT, Kharagpur (W.B.), India. – 721302

BIS (1971). Guide for sensory evaluation of foods. Optimum requirements IS: 6273 (Parts-II). Bureau of Indian Standards, New Delhi.

Blöchl A, Peterbauer T, Hofmann J and Richter A (2008). Enzymatic breakdown of raffinose oligosaccharides in pea seeds. Planta. 228:99–110

Boonyasirikool P and Charunuch C (2000). Development of Nutritious Soy Fortified Snack by Extrusion Cooking. Kasetsart Journal of Natural Science, 34:355 - 365.

Box GEP and Hunter JS (1957). Multi-factor experimental designs for exploring responses. Annals of Mathematical Statistics, 28:195-241.

Brooker BD, Bakker FW and Hall CW (1974). Drying cereal grains. AVI Publishing Co., Westport, Connecticut, USA.

Bukhari MA, Ayub M, Ahmad R, Mubeen K and Waqas R (2011). Impact of different harvesting intervals on growth, forage yield and quality of three pearl millet (*Pennisetum americanum L*.) cultivars. International Journal for Agro Veterinary and Medical Sciences, 5(3):307-315.

Cade JE, Berley VJ and Greenwood DC (2007). Dietary fiber and risk of breast cancer in the UK Women Cohort study. International Journal of Epidemiology, 36:431-438.

Chandrasekar A and Shahidi F (2010). Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. Journal of agricultural and food chemistry, 58(11):6706-6714.

Chandrasekhar PR and Chattopadhyay PK (1989). Heat transfer during fluidized bed puffing of rice grains. Journal of Food Process Engineering, 11:147-157.

Chandrasekhar PR and Chattopadhyay PK (1991). Rice puffing in relation to its varietal characteristics and processing conditions. Journal of Food Process Engineering, 14(4): 261-277.

Chandrasekher G, Suryaprasad RD and Pattabiraman TN (1981). Natural plant enzyme inhibitors, a-Amylase inhibitors in millets. Journal of the Science of Food and Agriculture, 32:9–16.

Chandrashekhar PR (1989). Some studies on heated air fluidized bed puffing characteristics of rice, Unpublished Ph.D. thesis, PHTC, IIT, Kharagpur (W.B.), India – 721302

Chang CC and Chien JT (1997). Studies on microwave popping ratio of the dried rice (in Chinese). Journal of the Chinese Agricultural Chemical Society, 35:376-384

Chattopadhyay PK, Pardeshi IL and Nath A (2004). Deep fat frying characteristics of fryums and potato flakes. Food and bio process engineering. Proceedings of International Conference on emerging technologies in agricultural and food engineering, IIT, Kharagpur, December, 14-17, pp 389-395.

Chavan J, Kadam S (1989). Nutritional improvement of cereal by sprouting. Critical Reviews on Food Science and Nutrition, 28(5):401-437.

Chinnaswamy R and Bhatacharya KR (1983). Studies on expanded rice, physico-chemical basis of varietal differences. Journal of Food Science, 48:1604-1608.

Chinnaswamy R and Bhattacharya KR (1983[a]). Studies on expanded rice: optimal processing condition. Journal of Food Science, 48:1604-1608.

Chinnaswamy R and Bhattacharya KR (1983[b]). Studies on expanded rice. Physico-chemical basis of varietal differences. Journal of Food Science, 48:1600-1603.

Choi YY, Osada K, Ito Y, Nagaswa T, Choi MR and Nishizawa N (2005). Effects of dietary protein of Korean foxtail millet on plasma adiponectin, HDL-cholesterol, and insulin levels in genetically type 2 diabetic mice. Journal of Bioscience, Biotechnology and Biochemistry, 69:31-37.

Collins WG, Saunders GG (1976). Changes in trypsin inhibitor activity in soybean varieties during maturation and germination. Journal of Food Science,41:168

Cook F and Brigg GM (1977). Nutritive value of eggs. In “Egg Science and Technology”, WJ, Sladelman and PJ Cotteril (eds) 2nd Ed. Pp 92-108.

Cooper H. (1988). Milling moves. Food Processing, April:41-42.

Copeland LO and McDonald MB (1995). Principles of seed science and technology. New York: Chapman and Hall, pp. 409

Cording JJ and Eskew RK (1962). Process for manufacturing rapidly rehydrated dehydrated fruit and vegetable U.S. Patent 3 038 813.

Crawford GW (2006). Formative Development: East Asian Plant Domestication. In: Stark MT. Archaeology of Asia. 1ed. Massachusetts (MA). Blackwell Publishing. 107-120.

Cruzycelis LP, Rooney LW, & McDonough CM (1996). A ready-to-eat breakfast cereal from food-grade sorghum. Cereal Chemistry, 73(1):108-114.

Dahlin K and Lorenz K (1992). Protein digestibility of extruded cereal grains. Food Chemistry, 48:13-18.

Das H (2005). Food Processing Operations Analysis, Asian Books Private Ltd., New Delhi (India).

Deshpande HW and Poshadri A (1999). Physical properties and sensory characteristics of extruded snacks prepared from Foxtail millet based composite flours. International Food Research Journal, 18(10):10-16.

Deshpande HW and Poshadri A (2011). Physical and sensory characteristics of extruded snacks prepared from Foxtail millet based composite flours. International Food Research Journal 18: 751-756.

Devaraju B, Mushtari JB, Shemshad B and Vidya K (2008). Finger millet pasta fortified with plant and animal protein and their sensory qualities. Journal of dairy, Food and Horticulture Sciences, 27 (3/4):193-195.

Devi PB, Vijayabharathi R, Sathyabama S, Malleshi NG and Priyadarisini VB (2011). Health benefits of finger millet (*Eleusine coracana L.)* polyphenols and dietary fiber: a review. Journal of Food Science and Technology, DOI:10.1007/s13197-011-0584-9. Posted November 22, 2011.

Dhaliwal YS and Aggarwal RK (1999). Composition of fat in soybean as affected by duration of germination and drying temperature. Journal of Food Science and Technology, 36(3):266-267.

Dhumal CV (2010). Development of barnyard millet based ready-to-eat (RTE) fasting food. Unpublished M. Tech. Thesis submitted to Department of Agricultural Process Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) – 444 104

Dhumal CV, Pardeshi IL, Sutar PP and Jayabhaye RV (2014). Development of potato and barnyard millet based ready-to-eat (RTE) fasting food. Journal of Ready to Eat Foods, 1(1):11-17.

Dublish RK, Chauhan GS and Bains GS (1988). Nutritional quality of extruded rice, ragi and defatted soy flour blends. Journal of Food Science Technology, 25(1):35.

Edwards CH, Booker LK, Rumph CH, Wright WG and Ganapathy SN (1971). Utilization of wheat by adult man: Nitrogen metabolism, plasma amino acids and lipids. American Journal Clinical Nutrition, 24:181-193.

Eggum BO, Juliano BO and Maniñgat CC (1982). Protein and energy utilization of rice milling fractions by rats. Plant Foods Human Nutrition, 31:371-376.

Eskew RK, Cording JJ, Sullivan JF and Eisendhardt NH (1962). Quick cooking dehydrated vegetable pieces. II. Process for carrot and beets. Paper presented at first Int. Congress of Food Science and Technology, London.

FAO (1970). Amino acid content of foods and biological data on proteins. FAO, Rome, p 84.

FAO. (2009). FAOSTAT. Food and Agriculture Organisation of the United Nations. FAOSTAT. http://faostat.fao.org/site/339/default.aspx

Fast RB (1987). Breakfast cereals: processed grains for human consumption. Cereal Foods World, 32(3):241.

Fast RB and Caldwell EF (1990). Breakfast cereals and how they are made**.** Amer. Assoc. Cereal Chem., St Paul, Minnesota, U.S

Fidrianny I, Puspitasari N, Marlia SW (2014). Antioxidant activities, total flavonoid, phenolic, carotenoid of various shells extracts from four species of legumes. Asian Journal of Pharmaceutical Clinic Research, 17:42–46.

Florence SP, Urooj A (2011). Influence of Processing on Dietary Fiber, Tannin and in Vitro Protein Digestibility of Pearl Millet. Journal of Food and Nutrition Sciences, 2:895-900.

Franzese (1981). 'Survey examines hospitals' use of convenience foods. Hospitals, 55(2):109.

Fritch CW (1981). Measurements of frying fat deterioration: A brief review. Journal of the American Oil Chemists Society, 58:272-274.

Gabrovska D, Fiedlerova V, Holasova M, Maskova E, Smrcinov H and Rysova J (2002). The nutritional evaluation of underutilized cereals and buckwheat. Food and Nutritional Bulletin, *23*:246–249.

Gandhi AP, Mishra VK and Ali N (1983). Organoleptic assessment of full-fat soy flour in various indigenous products. Journal of Food Science and Technology, 18:771-775.

Geankoplis CJ (1983). Transport Processes and Unit operations. Allyn & Bacon, Boston, MA, USA.

Geervani P and Eggum BO (1989). Nutrient composition and protein quality of minor millets. Plant Foods for Human Nutrition, 39(2):201-208.

Geervani P and Eggum BO (1989). Nutrient composition and protein quality of Minor millets. Plant Foods Human Nutrition, 39(2):201 208.

Ghavidel RA and Prakash J (2007). The impact of germination and dehulling on nutrients, antinutrients, in vitro iron and calcium bioavailability and in vitro starch and protein digestibility of some legume seeds. Swiss society of Food Science and Technology- LWT, 40(7):1292-1299.

Giami SY (1993). Effect of processing on the proximate composition and functional properties of cowpea *(Vigna unguiculata*) flour. Food Chemistry 47: 153-158.

Gopalakrishnan J, Menon R, Gourikutty P, Sajeev SM and Moorthy SN (2011). Nutritional and functional characteristics of protein- fortified pasta from sweet potato. Food and Nutrition sciences, 2:944-955.

Gopalan C, Ramasastri BV and Balasubramanian SC (2002). Nutritive value Of Indian Foods. National Institute of Nutrition, (ICMR), Hyderabad, pp. 47.

Gopalan C, Shastri R and Balasubramaniam SC (1999). Nutritive value of Indian Foods, NIN, ICMR, Hyderabad: 48.

Grobelnik MS, Bavec M, Turinek M, Bavec F (2009): Rheological properties of dough made from grain amaranth-cereal composite flours based on wheat and spelt. Czech Journal of Food Science, 27:309–319.

Guy R (2001). Extrusion Cooking: Technology and Applications. Woodhead publishing limited, Cambridge, England.

Guy RC E and Horne AW (1988) Cereals for extrusion cooking processes: a comparison of raw materials derived from wheat, maize and rice. 35th Technology Conference 1988. Biscuit, Cake, Chocolate and Confectionery Alliance**,** 45-49,

Guy, R.C.E. and A.W. Horne. 1988. Cereals for extrusion cooking processes: A comparison of raw materials derived from wheat, maize and rice. *35th Technology Conference 1988. Biscuit, Cake, Chocolate and Confectionery Alliance,* 45-49.

Haber A, and Runyon R (1977). General Statistics, 3rd Ed. Reading, MA: Addison-Wesley Publishing Company.

Hadimani N, Ali S and Malleshi N (1995). Physico-chemical composition and processing characteristics of pearl millet varieties. Journal of Food Science and Technology, 32:193-198.

Hadimani NA, and NG Malleshi (1993). Studies on milling, physico-chemical properties, nutrient composition and dietary fibre content of millets. Journal of Food Science and Technology, 30(1):17-20.

Hailand WK, Sillivan JF, Konstance RP, Craig JC, Cording JJ and Aceto NC (1977). A continuous explosion puffing system. Journal of Food Technology, 31(11):32.

Hegde PS, and Chandra TS (2005). ESR spectroscopic study reveals higher free radical quenching potential in kodo millet *(Paspalum*

scrobiculatum) compared to other millets. Food Chemistry, 92(1): 177-182.

Hoke K, Housova J, Houska M (2005). Optimum conditions of rice puffing. Czech Journal of Food Sciences, 23(1):1–11.

Hoseney RC (1986). Breakfast cereals. Principles of Cereal Science and Technology**.** Amer. Assoc. Cereal Chem., St Paul, Minnesota, U.S.A.

Huang L.R., Cai M.H., Zhong Y.H. (2011): Effect of germinate temperature on mung bean sprout antioxidants and antioxidant capacity. Journal of Anhui Agricultural University, 38:31–34.

Huang MT and Ferraro T, (---). Phenolic compounds in food and cancer prevention. In: Phenolic Compounds in Food and Their Effects on Health II, ACS Symposium Series, 507:28–34.

Ibrahim SS, Habiba RA, Shatta AA and Embaby HE (2002). Effect of soaking, germination, cooking and fermentation on antinutritional factors in cowpeas. Nahrung, 46(2):92–95.

Iles BC. and Elson CR (1972). Crispness. BFMIRA Research Report No. 190.

Ilo, S., and E. Berghofer. 1999. Kinetics of color changes during extrusion cooking of maize grits. Journal of Food Engineering, 39(3):73-80.

Indira R and Naik MS (1971). Nutrient composition and protein quality of some minor millets. Indian. Journal of Agricultural Science, 41: 795-797.

Iwe, M. O. 1998. Effects of extrusion cooking on functional properties of mixtures of full-fat soy and sweet potato. Plant Foods for Human Nutrition, 53(4):37-46.

Jansen GR, Harper JM and O' Dean, LD (1978). Nutritional evaluation of blended foods made with low-cost extruder cooker. Journal of Food Science, 43 (4):912.

Jayaraj AP, Tovey F and Clark CG (1980). Possible dietary protective factors in relation to the distribution of *duodenal ulcer* in India and Bangladesh. An International Journal of Gastroenterology and Herpetology, 21:1068-1076.

Jayaraman KS and Dasgupta DK (1992). Dehydration of fruits and vegetables-recent development in principles and techniques. Journal of Drying Technology, 10(1):41-50.

Jaybhaye RV and Srivastav PP (2010). Optimization of process parameters for development of millet based puffed snack food. International Conference on 'Food and Health' from 10–12th November, 2010 at Dublin, Ireland.

Jaybhaye RV and Srivastav PP (2010a). Oven toasting of barnyard millet based ready-to-eat (RTE) snacks: Process parameter optimization

and sensory evaluation. Proceedings of International Conference on 'Food Technology – Edition II' from 30 – 31 October, 2010 at IICPT, Tanajavur (T.N.)

Jaybhaye RV, Kshirsagar DN and Srivastava PP (2011). Development of barnyard millet puffed product using hot air puffing and optimization of process parameter. International Journal of Food Engineering, 1-15.

Joshi A, Rawat K and Karki B (2008). Millets as religious offering for nutritional, ecological and economical security. Comprehensive Review in Food Science and Food Safety 7:369-372.

Juliano BO and Sakurai J (1985). Miscellaneous rice products. In: Rice: Chemistry and Technology 2nd Ed. American Association of Cereal Chemistry, St Paul, Minnesota, U.S.A.

Kakade ML, Rackis JJ, Mcghee JE, and Puski G (1974). Determination of trypsin inhibitor activity of soy products: A collaborative analysis of an improved procedure. Cereal Chemistry, 51:376.

Kakade, ML, Simons N and Liener IE (1969). An evaluation of natural versus synthetic substrates for measuring the antitryptic activity of soybean samples. Cereal Chemistry, 46:518.

Kamaraddi V and Shanthakumar G (2003). Effect of incorporation of small millet flour to wheat flour on chemical, rheological and bread characteristics. In:Recent Trends in Millet Processing and Utilization, CCS Hisar Agril. Univ., Hisar, India, pp: 74-81.

Kamath MV and Belavady B (1980). Unavailable carbohydrates of commonly consumed Indian foods. Journal of the Science of Food and Agriculture, *31*(2), 194-202.

Kang RK, Jain R and Mridula D (2008). Impact of indigenous fiber rich premix supplementation on blood glucose levels in diabetics. American Journal of Food Technology, 3(1):50-55.

Katz EE and Labuza TP (1981). The effect of water activity on the sensory crispness and mechanical deformation of snack food products. Journal of Food Science, 46:403-409.

Giami SY (1993) Effect of processing on the proximate composition and functional properties of cowpea (Vigna unguiculata) flour Food Chemistry 47: 153-158

Katherine L, Domingo M, Pedreschi F, Jorge L (2006). Color measurement in L* a * b* units from RGB digital images. Food Research International, 39: 1084–1091.

Kaushik G, Satya S and Naik SN (2010). Effect of domestic processing techniques on the nutritional quality of the soybean. Mediterranean Journal of Nutrition and Metabolism 3(1):39-46.

Kawamura S, Tanusi S and Tado M (1970). Acid hydrolysis of soybean oligosaccharides at the iso electic pint of soybean globulins. Technical bulletion of faculty of Agriculture Kagawa University, 21(48):84-89.

Kejing A, Shenghua D, Hongyan T, Dandan Z, Wang X, Wang Z and Xiaosong H (2013). Response surface optimisation of osmotic dehydration of Chinese ginger (*Zingiber officinale Roscoe*) slices. International Journal of Food Science and Technology, 48:28–34.

Kent NL (1975). Technology of cereals with special reference to wheat, 2nd edn. Pergamon Press, Oxford, England.

Kent NL and Evers AD (1994). Technology of cereals: an introduction for students of food science and agriculture, 4th Ed. Pergamon Press, Oxford, England.

Khatoon N and Prakash J (2006). Nutrient retention in microwave cooked germinated legumes. Food Chemistry, 97(1):115-121.

Khattak AB, Zeb A, Bibi N, Khalil, SA and Khattak MS (2007). Influence of germination techniques on phytic acid and polyphenols content of chickpea (Cicerarietinum L.) sprouts. Food Chemistry, 104:1074-1079.

Khodke S and Chattopadhyay PK (2004). Optimization of the freeze-thawdehydration process for dehydrated instant potato cubes. Food and bioprocess engineering, Proceedings of International Conference on emerging technologies in agricultural and food engineering, IIT, Kharagpur, ANAMAYA Publishers, New Delhi, India, 381-388.

Khodke SU (2002). Freeze-thaw-dehydration technology for the production of instant potato cubes. Unpublished Ph.D. Thesis, Post-Harvest Technology Centre, IIT, Kharagpur (W.B.), India – 721 302.

Khuri AI and Cornell JA (1987). Response surfaces: Designs and Analysis. Marcel Dekkar, New York. 105-205.

Konishi Y, Iyota H, Yoshida KM, Moritani J, Inoue T, Nishimura N and Nomura T (2004). Effect of moisture content on the expansion volume of popped amaranth seeds by hot air and superheated steam using a fluidized bed system. Bioscience,Biotechnology and Biochemistry, 68(10):2186-2189

Kulkarni LR and RK Naik (1999). Chemical composition and protein quality Of Italian millet. Karnataka Journal of Agriculture Science, 12:164-167.

Kulkarni LR, Naik RK and Katarki PA (1992). Chemical composition of minor millets. Karnataka Journal of Agriculture Science, 5 (3):255-258.

Kumar KK and PK Parameshwaran (1998). Characterization of storage protein from selected varieties of foxtail millet (*Setaria italica (L) Beauv*). Journal Food and Agriculture, 77:535-542.

Kumari SK and Thayumanavan B (1998). Characterization of starches of proso, foxtail, barnyard, kodo, and little millets. Plant Foods for Human Nutrition, 53(1):47-56.

Kylen AM and McCready RM (1975): Nutrients in seeds and sprouts of alfalfa, Lentile, mungbeans and soybeans. Journal of Food Science, 40:1008–1009.

Lakshmi KP and Sumathi S (2002). Effect of consumption of finger millet on hyperglycemia in non-insulin dependent diabetes mellitus (NIDDM) subjects. Food Nutrition Bulletin, 23(3):241-245.

Lee J, Ye L, Landen WO and Eitenmiller RR (2000). Optimization of an extraction procedure for the quantification of vitamin E in tomato and broccoli using response surface methodology. Journal of Food Composition and Analysis, 13:45–57.

Lee J, Ye Landen WO, and Eitenmiller RR (2000). Optimization of an extraction procedure for the quantification of vitamin E in tomato and broccoli using response surface methodology. Journal of Food Composition and Analysis, 13:45–57.

Li J, Chen Z, Guan X, Liu J, Zhang M and Xu B (2008). Optimization of germination conditions to enhance hydroxyl radical inhibition by water soluble protein from stress millet. Journal of Cereal Science, 48:619–24.

Liang J, Han BZ, Nout MJR and Hamer RJ (2009). Effect of soaking and phytase treatment on phytic acid, calcium, iron and zinc in rice fractions. Food Chemistry 115:789-794.

Lorenz K and Dilsaver W (1980). Proso millets: Milling characteristics, proximate composition, and nutritive value of flours. Cereal Chemistry, 57(1):16-20.

Lucas GM and Markakas (1975). Phytic acid and other phosphorus compounds of bean (Phaseolus vulgaris). Journal of Agriculture Education Chemistry, 23:13-15.

MaCue P, Young IK and Shetty K (2005). Anti-diabetic and anti-hypertensive potential of sprouted and solid-state bioprocessed soybean. Asia pacific Journal of clinical nutrition, 14(2):145-152.

Malleshi NG and Desikachar HSR (1985). Milling, popping and malting characteristics of some minor millets. Journal of Food Science and Technology, 22: 400-403.

Malleshi NG, Desikachar HSR and Tharanathan RN (1986). Free sugars and non-starchy polysaccharides of finger millet (Eleusine coracana), pearl millet (Pennisetum typhoideum), foxtail millet (Setaria italica) and their malts. Food Chemistry, 20(4):253-261.

Manay NS and Shadaksharswamy M (2004). Food: Facts and Principles, New Age International (P) Ltd. Publishers, New Delhi, India.

Mani UV, Prabhu BM, Damle SS, and Mani I (1993). Glycemic Index of some commonly consumed foods in Western India. Asia Pacific Journal of Clinical Nutrition, 2:111-114.

Mariotti M, Alamprese C, Pagani MA and Lucisano M (2006). Effect of puffing on ultra-structure and physical characteristics of cereal grains and flours. Journal of Cereal Science, 43(1):47-56

Mariotti M, Alamprese C, Pagani MA, Lucisano M (2006). Effect of puffing on ultrastructure and physical characteristics of cereal grains and flours. Journal of Cereal Science, 43(1):47–56.

Matz SA (1970). Chemistry and Technology of Cereals as Food and Feed. AVI Publishing Co., Inc., West Port, Conn.

Mazumder P, Roopa BS and Bhattacharya S (2007). Textural attributes of a model snack food at different moisture contents. Journal of Food Engineering, 79:511-516.

MessinaMJ (1997). Soy foods: Their role in disease prevention and treatment. In K. Liu (Ed.), Soybeans: Chemistry, technology and utilization (pp. 442–466). New York: Chapman and Hall.

Monteiro PV, Sudharshana L and Ramachandra G (1988). Japanese barnyard millet *(Echinochloa frumentacea):* protein content, quality, and SDS-PAGE of protein fractions. Journal of Food and Agriculture, 43:17-25.

Montgomery DC (2001). Design and analysis of experiments (5th edition). New York: John Wiley., pp. 455–492.

Mostafa MM, Rahma EH and Redy AH, (1987). Chemical and nutritional changes in soybean during germination. Food Chemistry, 23:257 – 275.

Mudambi SR and Rajagopal MV (1983). The nutrients. In: Fundamentals of Food and Nutrition. Wiley Eastern Ltd., New Delhi

Mukherjee S (1997). Studies on HTST whirling bed dehydration technology for the production of RTE puffed potato cubes, Unpublished Ph.D. thesis, Post-Harvest Technology Centre, IIT, Kharagpur (W.B.), India– 721 302.

Mukherjee S (1997). Studies on HTST whirling bed dehydration technology for the production of RTE puffed potato cubes, Unpublished Ph.D. thesis, Post-Harvest Technology Centre, IIT, Kharagpur (W.B.), India– 721 302.

Mulimani VH, Thippeswamy S & Ramalingam (1997). Enzymatic degradation of oligosaccharides in soybean flours. Food Chemistry, 59(2):279–282.

Myers RH (1971). Response Surface Methodology. Boston: Allyn and Bacon, Inc.

Myers RH and Montgomery DC (2002). Response Surface Methodology. New York, USA: Wiley.

Nambiar VS, Dhaduk JJ, Sareen N, Shahu T and Desai R (2011). Potential Functional Implications of Pearl millet (*Pennisetum glaucum*) in Health and Disease. Journal of Applied Pharmaceutical Science, 1 (10):62-67.

Nambiar VS, Sareen N, Daniel M, and Gallego EB (2012). Flavonoids and phenolic acids from pearl millet *(Pennisetum glaucum)* based foods and their functional implications. Journal of Functional Foods in Health and Disease, 2(7):251-264.

Nath A (2006). Study on Process Technology for Production of Potato Based Ready-to-Eat Snacks Unpublished Ph.D. thesis, Post-Harvest Technology Centre, IIT, Kharagpur (W.B.), India–721 302.

Nath A and Chattopadhyay PK (2007). Optimization of oven toasting for improving crispness and other quality attributes of ready to eat potato-soy snack using response surface methodology. Journal of Food Engineering, 80(4):1282.

Nath A, Chattopadhyay PK and Majumdar GC (2007). High temperature short time air puffed ready-to-eat (RTE) potato snacks: Process parameter optimization, Journal of Food Engineering, 80:770–780.

Nonogaki H, Bassel GW and Bewley JW (2010). Germination-still a mystery. Plant Science doi:10.1016/j.plant sci.2010.02.010.

Nsofor LM and Osuji CM (1997). Stability, rheology and chemical properties of soymilk concentrates developed from sprout soybean. Journal of Food Science and Technology, 34(1):33-40.

Nsonzi F and Ramaswami HS (1998). Quality evaluation of osmo-convective dried blueberries. Drying Technology, 16:(3-5),705-723.

Obilana AB (2003). Overview: importance of millets in Africa. In: Belton, P. S.; Taylor, J. P. N. (Eds). Afripro, Workshop on the proteins of sorghum and millets: Enhancing nutritional and functional properties for Africa. Pretoria, South Africa, 2-4 April 2003.

Omwamba M and Mahungu SM (2014). Development of a Protein-Rich Ready-to-Eat Extruded Snack from a Composite Blend of Rice, Sorghum and Soybean Flour. Food and Nutrition Sciences, 5:1309-1317.

Pardeshi IL (2008). Development of Cereal Based Ready-To-Eat Snack Foods. Unpublished Ph.D. Thesis submitted to Department of Agricultural and Food Engineering. Institute of Technology, Kharagpur, West Bengal (India)-721302.

Pardeshi IL and Chattopadhyay PK (2014). Whirling bed hot air puffing kinetics of rice-soy ready-to-eat (RTE) snacks. Journal of Ready to Eat Food, 1(1):01-10.

Pardeshi IL and Tayade PT (2013). Development of appropriate process for sprouting of soybean. Journal of Food Research and Technology, 1(1):36-44.

Pardeshi IL, Murumkar RP and Tayade PT (2013). Optimization of process for spray drying of soymilk and sprouted soybean milk. Journal of Grain Processing and Storage, 1(1):13-20.

Pawar SG, Pardeshi IL, Borkar PA and Rajput MR (2014). Optimization of process parameters of microwave puffed sorghum based ready-to-eat (RTE) food. Journal of Ready to Eat Food, 1(2): 59-68.

Phillippy BQ and Johnston MR (1985). Determination of phytic acid in food by ion chromatography with post-column derivatization. Journal of Food Science, 50:541-542.

Plaza L, Ancos BD and Pilar M (2003). Nutritional and health related compounds in sprout and seeds of soybean, wheat and alfalfa treated by a new drying method. European Food Research and Technology, 216:138-144.

Pracha B and Chulalak C (2000). Development of nutritious soy fortified snack by extrusion cooking. Kasetsart Journal of Natural Science, 34:355-365.

Prasad K, Kaushik V, Sharma HK and Bera MB (2001). Soybean: A Boon to People. National seminar on emerging trends in processing, handling, storage and by-products utilization of pulses in soybean. Department of Food Technology, SLIET, Longawal-148106, Punjab. Pp:51-54.

Prince MV, Chattopadhyay PK and Mukherjee RK (1994). Studies on rheological properties of rice-soya crackers. Journal of Food Science and Technology, 31(6):469-471.

Pushpamma, P and Geervani P (1981). Nutritive value of traditional recipes of Andhra Pradesh. Hyderabad, India: Andhra Pradesh Agriculture University.

Quast DC and Karel M.(1972). Effects of environmental factors on the oxidation of the potato chips. Journal of Food Science, 37: 584-587.

Ramachandra G, Virupaksha TK and Shadaksha RM (1977). Relationship between tannin levels and in vitro protein digestibility in finger millet *(Eleusina Coracana Gaertn).* Journal of Agriculture Food Chemistry, 25:1101-1104.

Ramadan EA (2012) Effect of processing and cooking methods on the chemical composition, sugars and phytic acid of soybeans. Food Public Health, 2(1):11–15.

Randhir R, Shetty K (2007): Mung beans processed by solidstate bioconversion improves phenolic content and functionality relevant for diabetes and ulcer management. Innovative Food Science & Emerging Technologies, 8:197–204

Ranganna S (1995). Handbook of analysis and quality control for fruit and vegetable products. 2nd edition, New Delhi. Tata McDraw Hill Pub. Co. Ltd.

Rao R and Muralikrishna G (2004). Non-starch polysaccharide–phenolic acid complexes from native and germinated cereals and millet. Food Chemistry, 84(4):527-531.

Rastogi, A. and Singh, G. 1989. Effect of addition of full fat soy flour of different varieties on quality characteristics and bread making quality of white flour. Bulletin Grain Technology, 27:26-34.

Ravindra MR and Chattopadhyay PK (2000). Optimization of Osmotic pre-concentration and fluidized bed drying to produce dehydrated quick-cooking potato cubes. Journal of Food Engineering, 44(1):5-13.

Ravindran G (1991). Studies on Millets: Proximate composition, mineral composition and phytate and oxalate content. Food Chemistry, 39(3):99-107.

Ravindran G (1992). Seed proteins of millets: amino acid composition, proteinase inhibitors and in vitro digestibility. Food Chemistry, 44(1):13-17.

Reddy NR and Salunkhe DK (1980). Changes in oligosaccharides during germination and cooking of black gram and a fermentation of black gram/rice blend. Cereal Chemistry, 57:356-360.

Sadana B, Bakhetia P and Aggarwal R (2008). Nutritional evaluation of germinated wheat and soybean based supplementary foods. Indian Journal of Ecology, 35(1):87-90.

Saimanohar R, Vetrimani R, Leelavathi K, Rao PH, Prabhu TR and Prakash V (2005). Process for the preparation of a high protein nutritious baked snack food. US Patent, 12pp, 2005208191 A1 20050922.

Saleh AS, Zhang Q, Chen J and Shen Q (2013). Millet Grains: Nutritional Quality, Processing, and Potential Health Benefits. Comprehensive Reviews in Food Science and Food Safety, 12(1):281-295.

Sampath S, Madhava Rao T, Reddy K, Arun K and Reddy PV (2008). Effect of oligosaccharides in cereals and pulses. Journal of Food Science and Technology, 45(2):196-198.

Saputra D, Payne FA and Carnelius PL (1991). Puffing of dehydrating green bell pepper with carbon dioxide. Transition of Asian Society of Agricultural Engineers, 34(2):475-480.

Sawant AA, Thakur NJ, Swami SB and Divate AD (2013). Physical and sensory characteristics of Ready-To-Eat food prepared from finger millet based composite mixer by extrusion. Agricultural Engineering International: CIGR journal, 15(1):100-105.

Segnini S, Pedreschi F and Dejmek P (2004). Volume Measurement Method of Potato Chips. International Journal of Food Properties, 7(1),37-44.

Senratna T and McKersie (1983). Dehydration injury in germinating soybean seeds. Department of crop science, university of Guelph, Guelph, Ontario NIG 2W1 Canada. Journal of plant physiology,72:620-624.

Shahzadi N, Butt M, Rehman SUR and Sharif K (2005). Chemical characteristics of various composite flours. International Journal of Agriculture and Biology, 7(1):105-108.

Sharma A and Kapoor AC (1996). Levels of anti-nutritional factors in pearl millet as affected by processing treatments and various types of fermentation. Plant foods human nutrition, 49(3):241-52.

Sharma PD (1998). Studies on conduction heating as an alternative indigenous process for making instant flour from white maize. Unpublished Ph.D. Thesis, Post-Harvest Technology Centre, IIT, Kharagpur (W.B.), India – 721 302.

Shashi BK, Sharan S, Hittalamani S, Shankar AG and Nagarathna TK (2007). Micronutrient composition, anti-micronutrient factors and bio-accessibility of iron in different finger millet (*Eleucine coracana*) genotype. Karnataka Journal of Agriculture Science, 20(3):583-585.

Shilton NC and Niranjan K (1994). Department of Food Science and Technology, Univ. of Reading, Ehitenights, UK. IChemE Res. Event, Two-Day Symposium. 1489-91.

Shukla K and Srivastava S (2011). Evaluation of finger millet incorporated noodles for nutritive value and glycemic index. Journal of Food Science and Technology, DOI: 10.1007/s13197-011-0530-x.

Silva FAM, Borges F, Guimarães C, Lima JLFC, Matos C,Reis S (2000). Phenolic acids and derivatives: Studies on the relationship among structure, radical scavenging activity, and physicochemical parameters. Journal of Agriculture and Food Chemistry, 48:2122–2126.

Singh J (2000). Processing and utilization of legumes, Report of the APO Seminar on processing and utilization of Legume. The Asian Productivity Organization, Hirakawacho, Chiyoda-ku, Tokiyo, Japan, 1:2-10.

Singh JK, Azeem Z and Singh SS (2003). Comparative studies on extruded snack foods with khesari dhal and chickpea flours. Journal of Food Science and Technology, 40(3):333–336.

Singh P, Raghuvanshi RS (2012). Finger millet for food and nutritional security. African Journal of Food Science, 6(4):77–84.

Singh P, Singh G, Srivastava S and Agarwal P (2005). Physico-chemical characteristics of wheat flour and millet flour blends. Journal of Food Science and Technology, 42(4):340-343.

Sonone VS (2012). Study on the development of finger millet based pasta. Unpublished M. Tech. Thesis, Deptt. Of Agricultural Process Enginering, DR. PDKV, Akola.

Sridhar R and Lakshminarayana G (1994). Contents of total lipids and lipid classes and composition of fatty acids in small millets: foxtail *(Setaria italica),* Proso *(Panicum miliaceum)* and Finger millet *(Eleusine coracana).* Cereal Chemistry, 71:355–359.

Srinivas T and Desikachar HSR (1973). Factors affecting the puffing quality of paddy. Journal of Science Food Agriculture, 24:883-891.

Srinivas T, Lakshmi TK and Desikachar HSR (1974). Varietal differences in puffing quality of paddy. Journal of Food Science and Technology, 11:134-135.

Stat-Ease Inc. (2016). Design Expert User's Guide; Design Expert Version 10.0.3, The Stat-Ease Inc., MN, USA.

Sullivan JF, Konstance RP, Aceto NC, Heiland WK and Craig JJ (1977). Continuous explosion puffing of potatoes. Journal of Food Science, 42:1462.

Sullivan JF, Konstance RP, Aceto NC, Heiland WK and Craig JJ (1981). Carrot dehydration optimization process studies on the explosion puffing process. Journal of Food Science, 46 (5):1537-1542.

Sullivan JF, Konstance RP, Culhoun MJ, Talley FB, Cording JJ and Panasiuk O (1974). Flavour and storage stability of explosion puffed potatoes: non-enzymatic browning. Journal of Food Science, 39(1):58-60.

Suman CN, PV Monteiro, Ramachandra G and Sudarshana L (1992). In-vitro enzymic hydrolysis of the storage proteins of Japanese barnyard millet *(Echinochloa frumentacea).* Journal of the Science of Food and Agriculture, 58 (4):505–509.

Swaminathan M (1985). Nutritive value of common food preparations. In Essential of Food and Nutrition, II: 24–42.

Swarnakar AK, Devi KM and Das SK (2014). Popping characteristics of paddy using microwave energy and optimization of process parameters. International Journal of Food Studies, 3:45-59.

Tariqual I, Choudhury AFM, Islam MGF, Islam MS (2007). Standardization of bread preparation from soybean flour. International Journal of Sustainable Crop Production, 2(6):15-20

Taussky HH, & Shorr E (1953). A micro-colorimetric method for the determination of inorganic phosphorus. Journal of Biological Chemistry, 202:675–682.

Tayade PT (2010). Comparative investigation on spray dried powder from soymilk and sprouted soybean milk. Unpublished M.Tech. Thesis submitted to Department of Agricultural Process Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola-444104. Maharashtra.

Tharise N, Julianti E and Nurminah M (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternative of wheat flour. International Food Research Journal, 21(4):1641-1649.

Thimmaiah SR (2006). Methods of biochemical analysis. Kalyani Pub., N. Delhi (India).

Udayasekhara RP And Deosthale YG (1988). In vitro availability of iron and zinc in white and coloured ragi *(Eleusine coracana):* role of tannin and phytate. Plant foods Human Nutrition, 38(1):35-41.

Ugare R (2008). Health benefits, storage quality and value addition of barnyard millet *(echinochloa Frumentacaea link).* Unpublished M.Sc. (Home Science) Thesis submitted to Department of food science and nutrition, College of rural home science, university of agricultural sciences, Dharwad.

Vachanth MC, Subbu KM, Rathinam RP and Loganathan M (2010). Controlled atmoshpheric storage techniques for safe storage of processed little millet. Academic Journal of Entomology, 3(1):13-16.

Varela G, Bender AE and Morton ID (1988). Frying of foods. Ellis Horwood Ltd., Chichester, UK.

Verma P and Mehta U (1988). Study of physical charateristics, sensory evaluation and effect of sprouting, cooking and dehulling on the antinutritional factors of rice bran. Department of Food and Nutrition, College of Home Science, Punjab Agricultural University, Ludhiana, Punjab, India. Journal of Food Science and Technology, 25(4):197-200.

Vijayakumar PT, Mohankumar JB (2009). Formulation and characterization of millet flour blend incorporated composite flour. International Journal of Agricultural Science, 1(2):46–54.

Wang Q, Ke L, Yang D, Bao B, Jiang J and Ying T (2007). Change in oligosaccharides during processing of soybean sheet. Asia Pacific Journal of Clinical Nutrition, 16:89-94.

Watanabe M (1999). Anti-oxidative Phenolic Compounds from Japanese Barnyard Millet (*Echinochloa utilis*) Grains. Journal of Agriculture and Food Chemistry, 47:4500-4505.

Weng W, Liu W, and Lin W (2001). Studies on the optimum models of the dairy product Kou Woan Lao using response surface methodology. Asian–Australasian Journal of Animal Sciences,14(10):1470–1476.

Yam KL and Papadakis SE (2004). A simple digital imaging method for measuring and analyzing colour of food surfaces. Journal of Food Engineering, 61:137-142.

Zabik ME Fierke SG and Brsitol DK (1979). Humidity effects on textural characteristics of sugar-snap cookies. Cereal Chemistry, 56, pp 29.

APPENDIX - I

Specifications of Instruments/Equipment used in Experimentation

1. Balance

Type	: Digital balance
Model	: DJ- 3005
Capacity	: 300 g
Accuracy	: 0.001 g
Power	: DC-9 V
System	: Tunings-fork Vibration
Make	: Sinko Densi Co. Ltd.

2. Dolly Mini P3 Pasta Machine

Capacity	: max 2 kg flour
Power	: DC-9 V
Revolutions	: 60 RPM
Make	: LaMonferra, Italy

3. Hot air oven

Type	: Digital control
Power	: DC-230 V
Temperature	: 0-300 ℃
Make	: Indosaw, Ambala

4. Kjelplus apparatus

Type	: Kjelplus apparatus
Model	: DJ- 3005
Capacity	: 0.2 g
Power	: DC-230 V
Temperature	: 200-400 ℃
Make	: Pelican

5. Microwave Oven

Type	: Microwave heating system
Input range	: 210-230 V AC 50 Hz
Microwave Power	: 1.35 KW
Microwave Frequency	: 2450 MHz
Convection	: 2.55 KW
Make	: BPL Sanyo

6. Muffle Furnace

Type	: Muffle Furnace
Power	: DC-230 V
Temperature	: 550-650 ℃
Make	: Riviera Dass Pvt. Ltd, Mumbai

7. Pressure cooker

Type	: Muffle Furnace
Power	: DC-230 V
Temperature	: 550-650 ℃
Make	: Riviera Dass Pvt. Ltd, Mumbai

8. Pressure cooker

Type	: Pressure cooker
Moedl	: ISI 2347
Power	: DC-230 V
Pressure	: 1 kg/cm^2
Make	: Reliance Magic

9. Soxlet Apparatus

Type	: Siphon type
Capacity	: Six units
Power	: DC-230 V
Pressure	: 1 kg/cm^2
Make	: Pinlican

10. Texture Analyzer

Model	: TA.XT-2i
Make	: Texture Tech. Corp.,
Stable	: Microsystems, UK
Load cell	: 5 and 25 kg
Software program	: XT.RA Dimension

11. Water Activity Meter

Model	: CX2
Make	: Aqua Lab
Manufacturer	: Dicagon Devices Inc., USA

12. Colorimeter

Type	: Digital
Model	: KB- 191
Wave Length	: 400- 700 nm
Optical system	: Glass Filters
Accuracy	: 0.01
Power	: AC Mains: 230V, 50 Hz

APPENDIX-II

Calibration values of microwave oven

Sr. No.	Rated Power (W)	Actual Power (W)
1	540	260
2	675	325
3	810	390
4	945	455
5	1080	520
6	1215	585
7	1350	650

APPENDIX-III

Quality parameters obtained during microwave puffing of composite flour based RTE snack food

S. N.	Independent Parameters				Responses				
	Convective heating temp, ℃	Convective heating time, s	Microwave power, W	Microwave heating time, s	MC, kg/kg dm	HD, g	CSP, +ve picks	ER	Color, L-value
1	180	130	455	150	0.0632	1389.1	4	1.53	44.16
2	200	130	455	150	0.0464	2356.36	6	1.37	42.54
3	180	150	455	150	0.0448	1243.91	5	1.25	43.26
4	200	150	455	150	0.0481	1363.59	7	1.03	43.13
5	180	130	585	150	0.0472	875.05	6	1.9	42.91
6	200	130	585	150	0.0331	1899.22	9	1.38	40.76
7	180	150	585	150	0.03	1338.08	7	1.77	42.12
8	200	150	585	150	0.041	1381.25	13	0.95	44.45
9	180	130	455	170	0.0514	1473.46	4	1.77	43.07
10	200	130	455	170	0.0242	1192.9	10	1.56	46.57
11	180	150	455	170	0.0219	1759.91	8	1.75	40.08
12	200	150	455	170	0.0326	1520.55	11	1.43	39.50
13	180	130	585	170	0.0445	1487.2	9	1.99	42.84
14	200	130	585	170	0.0327	1548.02	14	1.25	43.72
15	180	150	585	170	0.034	1190.93	8	2.14	40.67
16	200	150	585	170	0.0351	1147.77	17	1.31	42.63
17	170	140	520	160	0.0477	963.34	11	1.92	44.17
18	210	140	520	160	0.0354	1493.08	11	1.08	44.68
19	190	120	520	160	0.0426	1298.84	5	2.05	48.61
20	190	160	520	160	0.0361	1536.25	9	1.68	44.48
21	190	140	390	160	0.0473	1320.43	6	1.01	46.03
22	190	140	650	160	0.0297	1334.16	16	1.11	38.48
23	190	140	520	140	0.0518	1447.96	12	1.75	42.56
24	190	140	520	180	0.0329	1394.98	17	2.18	41.21
25	190	140	520	160	0.0394	1355.56	16	2.17	40.44
26	190	140	520	160	0.0354	1445.99	18	2.23	41.52
27	190	140	520	160	0.0379	1336.12	20	2.2	40.79
28	190	140	520	160	0.0394	1285.11	17	2.27	41.67
29	190	140	520	160	0.0398	1322.39	19	2.23	40.44
30	190	140	520	160	0.0379	1524.54	16	2.17	43.75

APPENDIX-IV

Puffing Kinetics of sprouted soy fortified composite millet flour based RTE snacks at different microwave powers

Time, s	MC, %db At MP 390 W	MC, %db at MP 455 W	MC, %db at MP 520 W	MC, %db at MP 585 W	MC%db at MP 650 W
0	50.499	50.499	50.499	50.499	50.499
10	41.165	49.404	49.354	50.288	38.609
20	34.699	37.886	48.210	50.077	28.936
30	34.575	31.924	36.132	31.160	18.127
40	26.340	24.941	29.080	24.692	17.835
50	23.721	19.987	25.769	23.294	15.234
60	21.103	18.885	23.294	19.257	14.432
70	19.931	15.621	14.931	12.584	13.791
80	16.468	13.324	12.586	10.230	9.864
90	14.573	12.567	10.182	8.830	7.374
100	12.678	11.335	9.437	7.833	5.268
110	11.657	10.820	7.691	6.013	5.006
120	10.007	9.215	5.789	4.750	3.764
130	8.395	7.211	3.696	2.709	3.216
140	8.041	6.458	3.307	2.681	2.858
150	7.688	5.555	2.239	1.987	2.353
160	6.327	4.811	2.187	1.721	1.478

APPENDIX - V

Sensory evaluation sheet

Evaluation card for nine point hedonic rating test

Name: Date:

Product: Time:

Instruction: You are requested to assess the given samples in terms of the characteristics mentioned on the basis of nine-point hedonic scale given below:

Scale	**Score**
Liked extremely	9
Liked very much	8
Liked moderately	7
Liked slightly	6
Neither liked nor disliked	5
Disliked slightly	4
Disliked moderately	3
Disliked very much	2
Disliked extremely	1

Sample code	Quality characteristics				Comments (if any)
	Colour	Texture	Flavour	Overall acceptability	
1.					
2.					
3.					
4.					
5.					

Signature

APPENDIX-VI

Sensory evaluation of final product

Code	Quality Character	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	Mean	Factor mean
1	Colour	7	7	6	7	7	7	6	8	8	7	7	
	Texture	8	6	8	8	6	6	7	8	8	7	7.2	7.125
	Flavour	9	6	6	7	5	6	7	8	9	7	7	
	OAA	9	6	7	7	7	7	7	8	8	7	7.3	
2	Colour	7	6	7	6	6	8	7	6	7	7	6.7	
	Texture	8	6	9	7	7	7	7	5	8	6	7	6.675
	Flavour	9	6	7	7	5	7	2	6	8	5	6.2	
	OAA	9	9	8	7	6	8	2	6	7	6	6.8	
3	Colour	7	8	6	8	5	7	6	5	8	7	6.7	
	Texture	8	9	8	7	7	8	6	6	7	6	7.2	6.8
	Flavour	7	8	7	7	6	7	4	6	8	6	6.6	
	OAA	7	9	7	8	6	7	4	6	7	6	6.7	
4	Colour	7	9	6	8	7	6	7	8	7	7	7.2	
	Texture	8	9	6	7	7	8	7	7	8	6	7.3	7.325
	Flavour	8	9	7	8	6	8	6	8	8	6	7.4	
	OAA	8	9	6	8	7	7	6	8	9	6	7.4	
5	Colour	7	7	7	8	8	8	8	8	9	7	7.7	
	Texture	8	8	7	8	7	8	8	7	8	7	7.6	7.625
	Flavour	7	7	8	9	7	8	7	8	9	6	7.6	
	OAA	7	7	7	9	8	8	7	8	9	6	7.6	
6	Colour	7	7	8	8	8	8	8	8	9	8	7.9	
	Texture	8	8	9	8	7	8	9	7	8	7	7.9	7.975
	Flavour	7	7	8	9	7	8	7	8	9	8	7.8	
	OAA	8	8	7	9	8	8	9	8	9	9	8.3	

APPENDIX-VII

Values recorded for a_w against varied equilibrium moisture content of the product

Sr. No.	Moisture Content, kg/kg dm	Water Activity, a_w
1	0.0256	0.192
2	0.0348	0.201
3	0.0437	0.243
4	0.0526	0.384
5	0.0705	0.452
6	0.0794	0.502
7	0.1151	0.546
8	0.1329	0.637
9	0.1508	0.698
10	0.1864	0.759
11	0.1954	0.773
12	0.2132	0.786
13	0.2400	0.792
14	0.2667	0.824
15	0.2756	0.879
16	0.3202	0.901
17	0.3649	0.907

APPENDIX-VIII

Change in moisture content (kg/kg dm) during storage period

Sr. No.	Storage temperature 45 ℃		
	Relative Humidity 95 %		
	days	HDPE	MP
1	0	0.0255	0.0255
2	7	0.0544	0.0421
3	14	0.0815	0.0584
4	21	0.1023	0.0728
5	28	0.1278	0.0913
6	35	0.1521	0.1058
7	42	0.1945	0.1354

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