DEVELOPMENT AND QUALITY EVALUATION OF NUTRIENT ENRICHED RTE PRODUCT

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DECLARATION

We hereby declare that this project report entitled **“DEVELOPMENT AND QUALITY EVALUATION OF NUTRIENT ENRICHED RTE PRODUCT”** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur

Date:28-01-2019

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CERTIFICATE

Certified that this project report entitled **“DEVELOPMENT AND QUALITY EVALUATION OF NUTRIENT ENRICHED RTE PRODUCT”** is a record of project work done jointly by ANUSREE ANIL (2015-06-005), NAYANA T K (2015-06-015) NIMISHA P M (2015-06-017) and PAVITHRA P A (2015-06-018) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship to them.

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DEDICATED TO OUR

PROFESSION OF

FOOD ENGINEERING

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SYMBOLS AND ABBREVATIONS

&	And
et al.	And others
AOAC	Association of analytical communities
a_w	Water activity
Ca	Calcium
Cm	Centimetre
℃	Degree Celsius
Db	Dry basis
DC	Direct current2
/	Divided by
=	Equal to
etc.	Et cetera
Gm	Gram
GDP	Gross domestic product
H	Hour
Hcl	Hydrochloric acid
HTST	High temperature short time
HP	Horse power

IBEF	India brand equity foundation
ISS	International service system
J	Journal
J	Joules
JSF	Jackfruit seed flour
K	Potassium
KJ	Kilo joule
Kcal	Kilo calorie
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kg	Kilo gram
>	Less than
≥	Less than or equal to
Max	Maximum
Mg	Magnesium
Mg	Milligram
Ml	Millilitre
Mm	Millimetre
Min	Mint
N	Normal
N	Newton

N	Nitrogen
NaCl	Sodium chloride
P	Phosphorous
PE	Polyethylene
%	Percentage
PF	Pumpkin flour
pH	Potential of hydrogen
±	Plus or minus
Rpm	Revolution per mint
RTE	Ready to eat
S	Second
S	Sulphur
SEI	Sectional expansion index
Spp	Species
v/s	Versus
Viz	Namely
Wb	Wet basis
w/w	Weight per weight
TAC	Total available carbohydrate
Zn	Zinc

INTRODUCTION

CHAPTER I

INTRODUCTION

The food processing sector is the largest industry in India and ranks five in terms of production consumption, export and expected growth. Availability of raw materials, changing lifestyles and appropriate fiscal policies has given a considerable push to the industry’s growth. The food sector contributes about 28% of India’s GDP (IBEF 2017). This sector serves a vital link between agriculture and industrial segments of the economy. Adequate focus strengthening this link is of critical importance to reduce wastage of agricultural raw materials.

Extrusion cooking is a thermo-mechanical process in which heat transfer, mass transfer, pressure changes and shear are combined to effects such as cooking, sterilization, drying, melting, cooling, texturing, conveying, puffing, mixing, kneading, conching, freezing, forming etc. Extrusion cooking is a modern high-temperature short time (HTST) processing technology. Extrusion processing was introduced by Harper for the first time to food material. It offers several advantages over other types of cooking processes, such as faster processing times and significant reduction in energy consumed, which consequently results in lower prices for the final products. The role of shear, temperature, moisture and feed composition are significant in the transformation of starch by extrusion (Harper, 1986). It has become an important technique in an increasing variety of food processes. The benefits of this technology are it is a low cost, variability of product shape, high quality production of new foods, higher productivity, inactivation of anti-nutritional factors.

Extrusion is classified into two types based on temperature (hot and cold extrusion). If the food is heated below 100ºC the process is known as cold extrusion. Typical food products include pasta, pet food etc. if the food is heated above 100ºC the process is known as hot extrusion (or extrusion cooking). Typical products include a wide variety of low density, expanded snack foods and ready to eat (RTE) puffed cereals.

Maize (Zea mays) belongs to family Poacea, also known as corn and it is the most important cereal grain in the world providing nutrients for humans and animals. Corn has become an attractive ingredient in the extrusion industry due to its attractive yellow colour and great expansion characteristics, which are one of the important parameters in the production of a cereal, based extruded snack food in terms of the functional properties of final product. Corn is nutritious, providing fiber, which aids in digestion, plus folate, thiamin, phosphorous, vitamin C, and magnesium (about 10% of the daily value for each). Corn flour is used as binder, filler, and thickener in pastry, cakes, meat industries. Gluten contains the protein fractions glutenin and gliadin. The gluten matrix is a major determinant of the properties of dough (extensibility, resistance to stretch, mixing tolerance, gas holding capacity).

Bengal gram is called Chickpea or Gram (Cicераritinum L.) in South Asia and Garbanzo bean in most of the developed world. Bengal gram belongs to family Leguminoseae. India is the major growing country of the world, accounting for 61.65 percent of the total world area under Bengal gram during 2002 and 68.13 percent of the total world production. The pulse proteins are rich in lysine and have low sulfur containing amino acids. It offers the most practical means of eradicating protein malnutrition among vegetarian children and nursing mothers.

Mung bean (*vigna radiate*), alternatively known as the green gram, mash or moong belongs to the family Fabaceae. It is a high source of protein, fiber, antioxidants and phytonutrients. It comprised of 48% protein.100g of mung bean contains 347 kcal energy, total fat content is 1.2g, 63g total carbohydrate, 16g dietary fiber, 7g sugar. Mung bean is a good source of minerals like calcium of 13%, iron of 37%, and magnesium of 47% of total mineral content. The mung bean is mainly cultivated in India, Pakistan, Bangladesh, Taiwan Korea and South Asia.

Mung bean contain high levels of antioxidant including phenolic acid, flavanol, caffeic acid, cinnamic acid reduces chronic diseases. Antioxidants such as vitexin and isovitexin prevent heat stroke. Mung bean lower “bad” LDL (low density lipoproteins) cholesterol level, therefore reducing heart disease risk.

The jackfruit (Atrocarpusheterophyllus) is a species of tree in the family Moraceae. Jackfruit seed powder is a rich source of dietary fibre, protein, carbohydrate, vitamins A, B, C and minerals. A 100g serving of jackfruit seeds offers about 185 calories. It also contains 7g of protein, 1.5g of fibre and less than 1g of fat. Seeds are also good source of thiamine and riboflavin. They also containing trace amounts of zinc, iron, potassium, copper and manganese. The main health benefits of jackfruit seed are it will combat anaemia, improves digestive health, boost vision, might reduce risk of blood clots, helps in building muscles, fight wrinkles, enhances hair growth.

Banana is a herbaceous plant of the family Musaceae. In terms of overall production, it is in the second place after citrus, accounting for about 16% of the total fruit production. There are two wild species of banana, namely *Musa acuminte* and *Musa balbisiana,* Banana pseudostem is the stem of banana plant, it produces a single bunch of banana before dying and then is replaced by pseudostem. Banana pseudostem having the properties of dissolving kidney stone.

The main objectives are:

1. To standardize the extrusion process parameters.
2. To standardize the composition of food from corn flour, jackfruit seed flour, Bengal gram flour, mung bean flour, pseudo stem powder, beetroot powder and pumpkin powder.
3. Quality analysis of extruded product.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 Raw materials

2.1.1Maize (*Zea mays*)

Extrusion cooking is a widely used process for elaborating different foods with a cereal base (Harper 1981, 1989: Fast 1991), the majority of which contain corn and are manufactured with semolina and flours as raw materials.

Onwulata *et al.* (2001) by incorporating whey protein concentrate (WPC) and sweet whey solids (SWS) at concentrations of 500 and 250 g/kg to corn, potato or rice flour prepared snack product using high and low shear extrusion processing conditions and reported that, increased specific mechanical energy (SME) was desired for expanding products. But as a result of incorporating WPC and SWS, SME was reduced. Quality indices for expansion and decreased breaking strength ($P<0.05$) indicates poor textural effects.

Palazuelos *et al.* (2006) studied the effects of extrusion feed moisture (16-30%) and barrel temperature (75-140°C) of third-generation expanded product by microwave heating. A blend of potato starch (50%), quality protein maize (35%) and soybean meal (15%) was used in the preparation of the snack food by single screw extruder with the help of central composite rotatable experimental design. The results indicated that when the barrel temperature was increased expansion ratio increased and bulk density decreased while feed moisture had no significant effect. Response surface methodology (RSM) showed the best expansion of extruded products at 28% feed moisture and 130°C barrel temperature.

Yu *et al.* (2013) prepared protein rich extruded products from corn flour blended with soy protein isolate (SPI), feed moisture (31.6-48.4 g/100 g) and process temperature (126.4-193.6°C). It has been observed that, a higher SPI (66.6 g protein/100 dry matter) and feed moisture content (48.4 g/100 g) increased the breaking stress (0.828 N/mm^2) and bulk density (0.864 g/ml), but decreased the expansion ratio (1.25), water solubility index (2.7 g/100 g), rehydration rate (49 g/100 g), colour L*(74.21) value, whereas higher feed moisture content increased color L*(87.37).

M. Kavya Reddy *et al*. (2014) developed the extruded Ready-To-Eat (RTE) snacks using corn, black gram, roots and tuber flour blends. Extrusion was carried out by mixing the flour blends in a proportion of 60–80: 20: 20 respectively and moisture was adjusted to 17–20 %. Different formulations were extruded at 80 ± 5 °C (heater I) and 95–105 °C (heater II) temperature, 300–350 rpm screw speed, 100 ± 10 °C die temperature and 15 ± 2 kg/h feed rate. A serving of 100 g of the snack can provide more than 400 Kcal and 10 g of protein.

Deepika Balfour *et al*. (2014) studied on the Development and Quality Evaluation of Extruded Fortified Corn Snack. Three different ratios of CM, OM and WPC were taken in the proportion of (90:7:3) for the first (80:16:4) second and (70:25:5) third treatment. Among the treatments the one with 80% and 70% CM were found nutritive. Depending upon the sensory attributes also the sample having 80% CM was found satisfactory for storage and is the most acceptable sample. Therefore the snack developed is a high fiber low calorie snack which can be recommended to the diabetic and obese people.

2.1.2 Jackfruit seed (*Artocarpusheteroplyllus Lam.*)

A study on the functional properties of raw and blended jackfruit seed flour for food application was carried out by Chowdhury *et al*. (2012). The work was done investigate the functional properties of raw and blended jackfruit seed flour with a view to provide useful information for effective utilization along with wheat flour and finally the study revealed that jackfruit seed has great potential in new food formulating along with wheat flour.

Abedin *et al*. (2012) studied the nutritive composition of jackfruit seed and found that the protein content was ranged from 13-18%. Crude fibre content of seed varied from 1.56-2.60%. Jackfruit is a good source of many mineral content like N, P, K, Ca, Mg, S, Zn, Cu etc. starch content in seed was ranged from 12.86-17.90%.

Indices	**Values (%dry matter)**
Moisture	14.07±0.04
Crude fat	2.55±0.09
Protein	9.03±1.09
Total mineral matter	3.01±0.01
Carbohydrate	70.26±0.06
Energy (Kcal/100 g)	382.79±1.20

Source: Oclooe*tal*.(2010)

Table 2.1 Physicochemical properties of JSF

The starch content of the seed increased with maturity and different location gave different seed content. Amylose content of jackfruit seed starch was found to be 32%. Tulyatan*et al*. (2002) reported on the good ability of the flour to bind water and lipid. The flour had good capacities for water absorption (25%) and oil absorption (17%) and the Brabender amylogram (6% concentration) of seed starch showed that its pasting temperature was 81℃ and its viscosity was moderate, remained constant during a heating cycle, and retrograded slightly on cooling.

Chowdhuri *et al.* (2012) conducted a study on functional properties of raw and blended jackfruit seed flour (JSF) for food applications and revealed that JSF has great potential in new food formulation along with the wheat flour. The different functional behaviour of raw and blended JSF were influenced by milling operation, concentration of NaCl, effect of pH on heating .

2.1.3 Beet root (*Beta vulgaris*)

NipatLimSangouan *et al. (*2010) studied optimization of extrusion conditions for functional ready-to-eat breakfast cereal prepared by mixed vegetable powder composed of purple sweet potato, red cabbage and beetroot. They investigated the effects of mixed vegetable powder level (8, 12 and 16%), screw speed (300, 350 and 400 rpm) and feed moisture content (13, 15 and 17%) on the physical and functional properties of extrudates in breakfast cereal production using response surface methodology (RSM) and Box-Behnken experimental design.

M. Kavya Reddy *et al.* (2013) studied development of extruded Ready-To-Eat (RTE) snacks using corn, black gram, beet roots and tuber flour blends. Extruded RTE snacks were prepared from flour blends made with corn flour, Bengal gram flour, roots and tuber flours in a proportion of 60–80: 20: 20 respectively and moisture was adjusted to 17–20 %.Different formulations were extruded at 80±5 °C (heater I) and 95–105 °C (heater II) temperature, 300–350 rpm screw speed, 100±10 °C die temperature and 15±2 kg/h feed rate In the present study the weight of the extrudates ranged from 0.16 ± 0.04 to 0.3 ± 0.11g. The study reveals that t incorporation of root and tuber flours in combination with corn and black gram flours can be effectively used to produce RTE extruded snacks by extrusion cooking.

2.1.4 Mung bean (*Vigna radiate)*

Piyapornsirikong *et al.*(2016) studied physico-chemical properties of pre gelatinized mung bean flour by drum drying and extrusion process. The temperature of drum was at 100, 120, and 140 °C. Extrusion condition was set at 3 levels of water pump (30, 45 and 60 %). The moisture and protein content of pre gelatinized flour ranging from 4.80 to 6.54% and 2.42 to 2.85% respectively. Extruded flour, the moisture content may affect colour change. Physically modified methods by drum drying and extrusion process can be used effectively to lower the gelatinization temperature of mungbean flour.

2.1.5 Bengal gram (*Cicer arietinum*)

Daya S Sing *et al*. (2014) studied extrusion characteristic of bengal gram brokens and maize flour blends for preparation of extruded snack food.Bengal gram (Cicerarientinum L.) brokens and maize (Zea maize L.) flour blends was used for the preparation of protein rich extruded product. In the preparation of this product, moisture content in blend were 10%, 15% and 20% and Bengal gram brokens to Maize blend ratio (BR) were10:90, 15:85, 20:80, 25:75, 30:70, with temperature temperature i.e. 80ºC, 85ºC, 90ºC, 95ºC and100ºC.It was found that SEI was highly correlated with moisture contents and blend ratio but not much affected by temperature. This result showed that WAI is directly proportional to average diameter of extrudates.

D J Nithya *et al*.(2015) done optimization of Process Variables for Extrusion of Rice-Bengal Gram Blends. Parboiled rice brokens and roasted bengal gram brokens were used for extrusion. The temperature has less effect compared to bengal gram level ($P \leq 0.05$). There is no significant effect on the screw speed with the expansion ratio. The reduction in the expansion ratio may be due to the increase in the protein content. The WSI and WAI of the extrudates ranged between 9 to 12.5 % and 5 to 6 g/g dry sample in the extrudates.

2.1.6 Pumpkin (cucurbita)

M.N. Norfezah*et al*.(2011) done Comparison of waste pumpkin material and its potential use in extruded snack foods. Extrusion done at temperature points within the barrel of 40, 60, 80, 100, 140, 160 and 180 ºC. Screw speed was maintained at

315 rpm, feed rate 6.75 kg/h, water rate was 0.29 L/h and die diameter 3 mm. An increase of the percentage of pumpkin flour in the extruded snack products resulted in a reduced product diameter and hence a decrease in the expansion ratio. The density of extrudates ranged from 140 to 500 kg/m3.

Anna peksa *et al*. (2015), done amino acid improving and physical qualities of extruded corn snacks using flours made from jerusalem artichoke (helianthus tuberosus), amaranth (amaranthuscruentus l.) and pumpkin (cucurbita maxima l). The ingredients used for extruded snack preparation were corn grits (control) enriched with flours from Jerusalem artichoke tubers (JAF), amaranth seeds (AF) and pumpkin tissue (PF). The addition of Jerusalem artichoke and pumpkin flours resulted in a decrease of lightness and an increase of Hunter's colour space a* coordinate (redness).

PhanlertPromsakhanaSakon Nakhon *et al*. (2018) done Optimization of pumpkin and feed moisture content to produce healthy pumpkin-germinated brown rice extruded snacks. The paddy rice Khao Dawk Mali, Pumpkin (Cucurbita moschata L.) and Corn grit flour blend was used for the preparation of the extrudate. The barrel temperature profile was set at 30ºC (zone 1), 40ºC (zone 2), 55 ºC (zone 3), 120 ºC (zone 4), 130 ºC (zone 5), 140 ºC (zone 6), and 130 ºC (zone 7 at the die plate). The feed rate was kept constant at 4.0 kg/h and the screw speed was maintained at 400rpm.The highest PF (30%) resulted in a significant ($p \leq 0.05$) decrease in the expansion ratio and a significant increase in the bulk density. Increasing the PF content from 10% to 30% along with increasing the feed moisture content (13%-19%) tended to result in low liking scores in all sensory attributes.

2.2 Conditioning and blending of raw materials

Garber *et al.* (1997) studied the effect of particle size (50-1,622 µm), screw speed (200-400 rpm) and feed moisture content (19-22%) on twin screw extrusion of corn meal and reported that product temperature, specific mechanical energy and torque generally showed no change within the particle size ranges from 100 to 1,000 µm, as the particle size increased >1,000 µm each value dropped significantly. Die pressure was influenced by the screw speed, particle size, and feed moisture content.

Singh *et al*. (2005) examined on the enhancement of process parameters of soy-sorghum blend with blend ratio (5, 10, 15, 20 and 25% of Soybean in blend), barrel temperature (80, 90 and 100°C) and feed moisture contents (15, 20 and 25%) in a single screw laboratory extruder for the preparation of ready to eat snack food. The effects of initial feed moisture content, barrel temperature and blend ratios on properties like bulk density, sectional expansion index (SEI) and crispness of extruded products were studied.

Charunuch*et al.* (2008) conducted studies on rice snack with mulberry leaf indicating health benefits for higher potential in commercial scale. The operating conditions are then investigated with twin screw extruder at varying mulberry powder content (5, 7.5 and 10%), screw speed (300 and 350 rpm) and feed moisture (13, 15, and 17%). The result showed that at higher mulberry content (10%), the product was difficult to operate with irregular shape and less expansion while lower screw speed (300rpm) and moderate moisture content (15%) gave suitable expansion of 8.3 and bulk density of 187 kg/m^3 with better preference in appearance.

2.3 Extrusion

Extrusion is done with relatively dry materials to plasticize food mass, to reduce microbial load, denature enzymes, gelatinize starch, and polymerize proteins and most importantly texturize the end product into a desirable form. Extrusion technologies have an important role in the food industry as efficient manufacturing processes. The importance of extrusion cooking over conventional cooking is mainly because of versatility, efficiency and economy of space and labour. There are two types of extrusion process: cold and hot extrusion.

Extrusion cooking is a multivariable unit operation which includes mixing, shearing, cooking, puffing and drying in one energy efficient, rapid continuous process. This process of high temperature short time (HTST) extrusion bring gelatinization of starch, denaturation of proteins, modification of lipids and inactivation of enzymes, microbes and many anti nutritional factors. The advantages of an extruded product would be the elimination of prolonged cooking by the consumer and less degradation of nutrients (Konstance *et al*. 1988).

Transport of material through extruders depends largely on friction at the barrel surface. Material flows forward (drag flow) owing to the action of screw and to a lesser extent, backwards along the barrel (pressure flow and leakage flow) (Harper and Jansen, 1985).The screw has a number of sections, including a feed section/ solid conveying to compress particles in to a homogenous mass, a kneading/melting section to compress, mix and shear the plasticized food and in high shear screws, a metering/cooking section (Leszek and Zuilichem 2011).

2.4 Optimisation and standardisation of extrusion process parameters

The process variables comprised of independent variables such as feed ingredients, composition, moisture content, particle size, extruder design, screw composition, die diameter, extruder operating condition, screw speed, feed rate and barrel temperature. Dependent variables includes extrudate properties such as bulk density, expansion ratio, texture, functional and sensory preferences and process data, material temperature, pressure, mixing profile, power consumption.

Yagci and Gogus (2008) used the RSM to investigate the effects of extrusion conditions including moisture content (12-18%), temperature (150-175°C), screw speed (200-280 rpm), and change in feed composition, durum clear flour (8-20%), partially defatted hazelnut flour (PDHF) (5-15%) and fruit waste (3-7%) contents on the physical and functional characteristics of the extruded snack food based on rice grit in combination with durum clear flour and partially defatted hazelnut flour. The results showed that the optimum operating extrusion process parameters were 168.8°C barrel temperature, screw speed of 280 rpm and feed moisture of 13.5%.

Jhoe *et al.* (2009) conducted study on soy-protein-fortified expanded extrudates using normal corn starch and showed that increasing screw speed resulted in higher specific mechanical energy (SME) and expansion, and lower mechanical strength. On the other hand, addition of 5-20% SPC (soy protein concentrate) led to lower SME and expansion, and higher mechanical strength. Water absorption index (WAI) increased and water solubility index (WSI) decreased with increase in screw speed and SPC level

Nath *et al.* (2010) developed potato-soy RTE snacks using high temperature short time (HTST) air puffing process. The process parameters including puffing temperature (185-255°C) and puffing time (20-60 s) with constant air velocity of 3.99 m/s and initial moisture content of 36.74% for potato-soy blend with varying soy flour content from 5% to 25% were examined using RSM following central composite rotatable design (CCRD).

2.5. Physical properties

2.5.1 Expansion ratio

The effect of process parameters on physicochemical properties of yam flour was done by Chang *et al.* (2001). Raw yam (*Dioscorearotundata*) flour was cooked and extruded in a single-screw extruder. RSM using an incomplete factorial design was applied with various combinations of barrel temperature (100, 125, 150°C), feed moisture content (18, 22, 26%) and screw speed (100, 150, 200 rpm). The physical properties of the extruded product showed a greater expansion index at high temperature and low moisture content.

Gujral *et al.* (2001) studied the effect of extrusion temperature (100-150°C), screw speed (100-150 rpm) and feed moisture (16-24%) on the extrusion behaviour of flint and sweet corn grits. The particle size distribution indicates that flint corn grits had more fine and opaque particles and resulted in extrudates with lower WSI and expansion than sweet corn grits which had fewer fine particles.

Mezreb *et al*. (2003) investigated the effect of screw speed on the expansion, physico-chemical properties and structural properties of both wheat and corn extrudates. A digital image technique was used to determine the structural properties. An increase in screw speed resulted in products with higher longitudinal expansion, water solubility and smaller structure patterns.

Shannon *et al.* (2010) studied the effect of protein (6, 12 or 18% db.), moisture content (15, 18 or 21% wb.) and barrel temperature (100, 120 or 140°C) on the physicochemical characteristics of pea flour extrudates and a leavening agent (0.5% sodium bicarbonate) was used. Extrusion of pea flour containing 6% of protein and 15% of moisture at a set temperature of 120°C resulted in expansion indices of 3.3 and 3.6 respectively in the absence or presence of the leavening agent.

M. O. Oke *et al.* (2013) studied on the expansion ratio of extruded water yam (Dioscorealata) starches using a single screw extruder This was accomplished by varying the feed moisture content (FMC) and extruder parameters which include barrel temperature (BT), screw speed (SS) and determine their effects on resulting expansion ratio using response surface methodology.

2.5.2 Bulk density and true density

Berglund *et al*. (1994) conducted physicochemical and sensory evaluation of extruded high-fibre barley cereals using a co rotating twin extruder.Cereals produced by extrusion of 100% barley have limited expansion high bulk densities. When blended with 50% rice, bulk densities were reduced by 50%, and appearance was similar to that of 100% rice cereal.

Wang *et al*. (1999) studied the effect of moisture, screw speed and barrel temperature on the physical, fuctional and nutritional characteristics of texturized pea protein using a twin screw extruder. Raising the screw speed from 135 to 245 rpm reduced bulk density from 0.57 to 0.32 g/cm^2 but increased water holding capacity from 1.92 to 2.21 g H_2O/g. bulk density decreased as barrel temperature was increased, whereas water holding capacity increased.

Boonyasirikool and charunuch (2000) produced a nutritious soy fortified snack with good texture and good protein quality with 2% soybean oil and fortified with a mixture of vitamins,minerals and amino acid. Mixed ingredients were adjusted to 16.5 ± 0.5% moisture content and fed at 365 g/min to extrusion process at 165 to 167°C melt temperature by twin screw extruder operated at 300rpm. The obtained snack has expansion ratio, bulk density and compression force 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.

Zeinab *et al.* (2010) studied on the physico-chemical characteristics of of extruded snacks enriched with tomato lycopene and summarized that increasing the processing temperature from 140ºC decreases the product density although the mean density value of products at 180ºC and 190ºC was similar.

2.5.3 Moisture content & water activity

Linko *et al.* (1982) studied the extrusion cooking and bio conservations of cereals and reported that at typical high temperatures and pressure prevailing in HTST extrusion cooking, a water activity (a_w approximately 1) may be reached even at well below 20% moisture, explaining the high degree of cooking obtainable during extrusion cooking of cereal based materials at very low moisture levels.

Onwulata *et al.* (2006) studied on the physical properties of extruded products as affected by cheese whey and reported that evaporation of water is a main cause of product expansion. Product expansion increased directly with decrease moisture at high shear, for whey substituted products.

Marzec*et al.* (2007) studied the influence of water activity on acoustic emission of flat extruded wheat bread and rye bread subjected to three-point breaking test. It was found that breaking of flat extruded bread generated vibrations in whole audible spectrum. Acoustic emission signal energy expressed in arbitrary units was more dependent on water activity in low frequencies region. Majority of acoustic emission events lasted 68.11 s, and their energy statistically was not dependent on water activity.

Meng *et al.* (2010) conducted a study on the effects of extrusion conditions on system parameters and physical properties of a chickpea flour-based snack food. RSM was used to study the effects of feed moisture content (16-18%), barrel temperature (150-170°C) and screw speed (250-320 rpm) on extruder system parameters and physical properties of a chickpea flour-based snack food. All three variables affected the product properties significantly, the products are characterized by high expansion ratio (4.99) and low bulk density and hardness, were obtained at low feed moisture (16%), high screw speed (320 rpm) and medium to high barrel temperature (160°C).

2.5.4 Water absorption index & water solubility index

Gujsha and Khalil (1990) reported on the effect of temperature properties of extrudates from high starch fraction of navy, pinto and garbanzo beans found that the water absorption index (WAI) of pintobeans increased significantly with an increased in temperature to 132℃. However, a further increase in temperature to 150℃ resulted in a decrease of WAI for navy bean as decomposition or degradation of starch began to take place. The water solubility index (WSI) of bean increased significantly with increasing temperature of extrusion. However, there were no significant difference between OAS of all extrudates at lower temperature (110,120℃).

Osman *et al*. (2000) studied the oil absorption characteristics of a multigrain extruded and fried snack product as a function of extruder screw speed and cooking temperature. The extruder, dehydrated to uniform moisture content and subsequently deep -fat-fried at 192± 1℃ for 10 to 40s to complete expansion. According to the lowest oil model absorption (19.9%) was absorption with an extruder screw speed of 218.6 rpm and cooking temperature of 117.8℃. Water absorption index reached a maximum of 8.8 at a screw speed of 221.9 rpm and a cooking temperature of 109℃. Oil absorption characteristics and extrudate water absorption index were correlated (r=0.84, p=0.0002)

Jorge and Maria (2003) studied the effect of extrusion conditions on the quality of cassava starch extrudate. Response surface methodology was used to determine the effect of the concentration of cassava bran (10-15%), barrel temperature (150-210℃) and screw speed (120-180rpm) on the characteristics of the dried extrudate.

2.6 Proximate analysis

2.6.1 Protein

Mary Omwamba *et al.* (2014) studied on Development of a Protein-Rich Ready-to-Eat Extruded Snack from a Composite Blend of Rice, Sorghum and Soybean Flour. The extruded product represents a good source of protein and dietary fiber.

SopidaKorkerd *et al.* (2015) studied that Expansion and functional properties of extruded snacks enriched with nutrition sources from food processing by-products. Increase of total dietary fiber from 4.82 % (wb) to 5.92–17.80 % (wb) and protein from 5.03 % (wb) to 5.46–13.34 % were observed. The RTE product contain higher amount of protein and fiber content.

Ashok A. Patel *et al.* (2015) studied on production of a protein-rich extruded snack base using tapioca starch, sorghum flour and casein.A protein-rich puffed snack was produced using a twin screw extruder and the effects of varying levels of tapioca starch (11 to 40 parts), rennet casein (6 to 20 parts) and sorghum flour (25 to 75 parts) on physico-chemical properties and sensory attributes of the product studied.The protein content of the extruded snack base ranged between 7.54 and 34.30 %.

2.6.2 Carbohydrate

Jabeen A *et al*. (2018) studied physico-chemical composition and functional properties of blended flour obtained from lentil, pumpkin and barley for development of extrudates. Raw materials used in the investigation are Barley, lentil and pumpkin. The independent variables included the feed composition (50% to 90% barley flour; 2.5% to 42.5% lentil flour; 7.5% pumpkin flour), moisture content (13% to 21%), and barrel temperature (115°C to 155°C).

J. De J. Berrios *et al*. (2010) studied Carbohydrate composition of raw and extruded pulse flour from lentil (Lens culinarisL.), dry pea (Pisum sativum L.) and chickpea (Cicer arietinum L.) were used for extrusion. The temperature of the last barrel section and the die was maintained at 160 ± 1℃. The screw diameter (D) was 32 mm and the total configured screw length (L) was 768 mm, which gave an overall L/D ratio of 24. The TAC concentrations in the pulse flour extrudates ranged from 525 to 639 g/kg dry weight, whereas those in the formulated pulse flour extrudates ranged from 629 to 738 g/kg dry weight. The pulse extrudates consistently exhibited lower TAC values than did the corresponding raw pulse flours, and this difference was significant ($p < 0.05$) in the case of chickpea.

P. Vijaya Deepthi *et al*. (2016) physico-chemical analysis of sorghum based extruded products. The samples were prepared from process parameters including three different blends of sorghum, broken rice and green gram in the ratios of (7:2:1, 6:3:1, 5:4:1) at feed moisture content (12%) and operational parameters of the extruder like barrel temperature (110, 120 and 140^0C) and screw speed (150, 200 and 250 rpm).

2.6.3 Fat

Dias *et al*. (2009) studied the increasing concerns about the health risk of saturated and trans – fatty acid consumption that led to the development of alternative agents for this use. Fatty acids composition, reactive substances , shear strength and sensory acceptability were assessed throughout storage time. Total replacement reduced saturated fat by 72.5% in relation to market available snacks.

2.7 Colour and texture

Bhattacharyya *et al.* (2006) examined the physico-chemical characteristics of extruded snacks prepared from rice, corn and taro by twin-screw extrusion at temperature 141, 150 and 159°C, respectively. The extractable protein decreased in all solvents after extrusion (0.127 to 0.039%). Loss of carbohydrate (maltose) was documented in extruded snacks. The results showed an increase in maltose content (1.92 to 4.16%) and decreasing breaking force (13.03 to 20.49 N) with increase in barrel temperatures from 141-159°C.

Anton and Luciano (2007) studied the instrumental texture evaluation of extruded snack foods. Texture evaluation of extruded snacks is a complex subject, where the combination of the techniques involves sensory, instrumental and microstructure analysis. From a practical perspective, empirical methods are suggested as alternative to fundamental techniques, especially to food scientists and food manufacturers interested in predicting consumer perception of texture.

The tri-stimulus colour values (L*, a* and b*) of small millets based *kurkure*products stored for a month in LDPE and PP film packages were reported by Sudha Devi, (2012). The lightness factor L* values slightly decreased after storage in both the packages. However, the chromaticity coordinate values a* and b* almost did not change from initial values of respective products.

Aneeshya*et al*. (2013) studied textural properties and economic feasibility of an extruded RTE snack from starch based food products. The raw materials were mixed in 2 different combinations namely, rice: banana (R:B) and rice: cassava: banana (R:C:B) in different proportions *viz*. R_{60}:B_{40}, R_{70}:B_{30}, R_{80}:B_{20}, R_{90}:B_{10}, R_{70}:C_{20}:B_{10}, R_{50}:C_{40}:B_{10}, R_{30}:C_{60}:B_{10} and R_{10}:C_{80}:B_{10}. These mixes were extruded under various extrusion process parameters of die temperatures (170, 180, 190 and 200°C), screw speed (80, 100, 120 rpm), feed rate (1.4 to 2.28 kg/h) and feed moisture content (16%).

Seema *et al*, (2016) studied on the development and quality evaluation of millet fortified tuber based extruded RTE products. The raw materials were mixed in seven different combinations namely: corn, corn : rice, corn : ragi, corn : elephant yam : purple yam : drumstick, ragi : elephant yam : purple yam : drumstick, ragi : corn : rice : elephant yam : purple yam : drumstick and rice : elephant yam : purple yam : drumstick in different proportions. These mixes were extruded under various extrusion process parameters of die temperatures (100, 110 and 120°C), screw speed (350rpm) and moisture content (17.5%)

2.8 Sensory analysis

Jing *et al.* (1991) reported on the effect of extrusion condition on sensory properties of corn meal extrudate and found that temperature and moisture had a significant effect on the flour aroma of extrudate. Increasing the temperature decreasing the moisture resulted in a marked increase in toasted corn taste probably related to the chemical reaction in corn meal during extrusion cooking. Screw speed has less effect on toasted corn taste.Thus the crispness of the extrudates were related to the denseness of the extrudates.

Hanna *et al* (2005) studied on the sensory quality of extruded oat, stored in light and darkness in packagers with different oxygen transmission rates (including use of an oxygen absorber),which was evaluated after 3 months of storage at 38°C and 10 months of storage at 23°C. The intensity of oat, paint odour and crispiness were found to describe the main difference among the sampleby increasing the temperature from 23 to 38°C for sample stored in darkness, packaging evaluation testes for extruded oat might be performed in approximately one third of the time.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the methodologies used to perform the preparation of samples, blending of prepared flours and experiments on extrusion of ingredients blended in different proportions under different process parameters. The chapter also describes the standardized methods to carry out the physical, and engineering properties of the developed extrudates and storage characteristics of best extrudates.

3.1 Raw materials

The main raw materials used for the development of the extruded product were corn and pulses like bengal gram and mung bean. In addition to this, pseudo stem, jackfruit seed, pumpkin, beetroot were also used. The raw materials were procured from local market.

3.1.1 Preparation of samples for extrusion

The raw materials were prepared by washing thoroughly, drying by a suitable process, and grinding to obtain dried powder. These are sieved manually using ISS 85 mesh in order to obtain uniform particle size.

3.2 Development of hot extruded RTE product

Ready to eat (RTE) crispy products were prepared from corn and pulse varieties by hot extrusion technology using a Laboratory model Twin screw extruder(L-TSE).

3.2.11 Laboratory model Twin screw extruder

Ready to eat (RTE) crispy products were prepared by hot extrusion technology using a Laboratory model twin screw extruder. The laboratory model Twin screw extruder (make: Basic Technologies, Kolkatta; model: L-TSE) is a compact but sturdy food processing equipment that can be used for scientific small scale extrusion product development. The main component of the extruder is twin stainless steel screws of uniform diameter rotating in opposite direction inside a sturdy stainless steel barrel. The main drive (10 hp motor; 440 V) is axially coupled to a reduction gear box. The out-put shaft of worm reduction gear of the gear box is provided with a torque limiter coupling. This device consists of a torque limiter and a roller chain type coupling. The torque limiter is a protective device having spring loaded friction surface. When there is any overload, the friction surfaces slip and smoke may come out if there is any oil contamination. The barrel of the extruder receives the feed from a co-rotating, variable speed, feeder placed just above the main extruder. The feeding rate of the feeder is controlled by a knob on the feeder controller. The barrel is provided with two electric band-heaters and water cooling jackets. There are two temperature sensors, one fitted on the front die plate and the other sensor is fitted near the feed hoper (feed zone) and both are connected to temperature controllers placed on the main panel board. At the end of the barrel (and screw), the die-plate of the die is fixed with the help of a screw-nut, tightened by a special hook type wrench. An automatic cutting knife is fixed on a rotating shaft of knife cutter powered by a DC motor. The cutter is actually driven by a variable speed controller which is controlled by a knob placed on the panel board.

The automatic knife cutter assembly is covered using a hinged safety guard. There is an emergency switch, conveniently placed at the centre of the extruder, to immediately stop the machine in case of emergencies.

Plate 3.1 Twin Screw Extruder

3.2.2 Working of Twin screw extruder

The heater control switches were put on after setting the temperature of barrel at the “die” and feed ends using the temperature controllers on the panel board. The extruder barrel was initially heated to attain desired temperatures and the valve of cooling water line to solenoid valve is opened to maintain barrel temperature. Then the machine was started and allowed to run empty for five minutes. Then the conditioned flour/grit mix of desired moisture content (17.5%) was fed continuously without any interruption in feeding. The cutter switch was put on and the cut extrudates were collected at die end. When cutter switch is in off position, a continuous extrudate could be obtained.

3.2.3 Optimization of Twin screw extruder operating parameters

The operating parameters of the twin screw extruder mainly, the feed moisture content and the screw speed, were optimized based on the previous studies. We have already done experiments with the following combinations of temperature and moisture content such as (160°C, 17%), (170°C, 18%), (140°C, 14%). The first two combinations were failed due to the development of off flavour.From these experiments we selected a temperature of 140℃ and feed moisture content of 14%.

3.2.4 Preparation of samples

The raw materials were blended in six different combinations mainly,

- C_1 - Corn : Mung bean : Jackfruit seed : Pseudo stem
- C_2 - Corn : Mung bean : Jackfruit seed : Beetroot
- C3- Corn : Mung bean : Jackfruit seed : Pumpkin
- C_4 - Corn : Bengal gram : Jackfruit seed : Pseudo stem
- C_5 - Corn : Bengal gram : Jackfruit seed : Beetroot
- C_6 - Corn : Bengal gram : Jackfruit seed : Pumpkin
- The amount of raw materials used to produce various flour blends constituted 500 g each are indicated in Table 3.1.

Combinations	Blends (%)	Quantity of raw materials
C_1	C_{60} :M_{30} : J_5 : PS_5	C300 : M150 : J25: PS25
C_2	C_{60} :M_{30} : J_5: B_5	C300 : M150 : J25: B25
C_3	C_{60} :M_{30} : J_5 : P5	C300 : M150 : J25: P25
C_4	C_{60} : BG_{30} : J_5 : PS_5	C300 : BG150 : J25: PS25
C_5	C_{60} : BG_{30} : J_5 : B_5	C300 : BG150 : J25: B25
C_6	C_{60} : BG_{30} : J_5 : P_5	C300 : M150 : J25: P25

Table 3.1 Proportions of raw materials

3.2.5 Experimental method

The blends of six different combinations were extruded at temperatures of 140ºC and 110ºC at constant speed of 350 rpm and 14% moisture content. Organoleptic and quality parameters of these processed snacks were done using standard engineering properties including physical, colour, textural and nutritional assessments. The second stage of the work includes the storage studies which were done with selected extrudates.

3.2.6 Extrusion of RTE products

The extruder was primed before actual operation and 3 mm circular “die” was fixed at the barrel end. The heater 1 was set at 140ºC and heater 2 was set at 60ºC and both were switched on for barrel heating. Cooling water line to solenoid valve is shut till required temperature was reached. The other operational settings namely, screw speed (350 rpm), feeder speed (35% of max) and cutter (30% of max) were set in the main control panel. When the required temperature was reached, the water line is opened for automatic barrel temperature control. Then the extruder (screws), feeder and cutter were switched on and initially higher moisture (30%) feed was fed to the barrel to lubricate the barrel and screws. When, the product just started coming out of die, the experimental feed was feed using the auto feeder. The uniformly cut, RTE product was collected just below the cutter assembly using trays. The products were transferred within few minutes to the PE bags, sealed and stored for further analysis.

3.3 Physical parameters of RTE expanded products

The following physical parameters are to be studied for the hot extruded RTE product.

3.3.1 Expansion ratio

The degree of expansion of extrudates was expressed as the ratio of diameter of extrudate to the diameter of “die” (Fan *et al.*, 1996). Ten pieces of extrudates were randomly selected and their diameter was measured with a verniercalliper. The mean of this ten measurements will give the diameter of the extruded product. The extrudates expansion ratio was then calculated as:

$$\text{Expansion ratio} = \frac{\text{Diameter of extruded product (mm)}}{\text{Diameter of die hole (mm)}}$$

3.3.2 Bulk density

The bulk density (BD) was calculated by measuring the actual dimensions of the extrudates (Chinnaswamy and Bhattacharya, 1986). Ten pieces of extrudate were randomly selected and their diameter and length were measured using digital vernier calliper with least count of 0.1mm. The average of these ten measurements will give the diameter and length of the extrudate (Ding *et al.*, 2005). The weight per unit length of extrudate was determined by weighing measured lengths (1cm). The experiments were repeated thrice and the bulk density was calculated by using the following equation assuming cylindrical shape of extrudate (Launay *et al*., 1983):

$$\text{Bulk density (g/cm}^3) = \frac{4\text{m}}{\pi d^2 L}$$

Where, m is the mass (g) of the extruded product, L is the length (cm) of extrudate and d is diameter (cm) of the extrudate.

3.3.3 True density

True density of extruded RTE products was calculated as per the method recommended by Deshpande and Poshadri (2011). A known weight (2 g) of extrudate was ground and the ground sample was poured into a burette containing toluene. The raise in volume in the burette was noted as the true volume of the sample. Then the true density was calculated as :

$$\text{True density (g/cm}^3) = \frac{\text{Weight of ground sample of extrudate (g)}}{\text{Rise in toluene level (cm}^3)}$$

3.3.4 Water activity (a_w)

Aqua lab water activity meter was used for the measurement of water activity. 2 g of ground sample was taken in sample cup which was provided with water activity meter. The reading displayed on the water activity meter was taken as water activity of the ground extrudate (Murphy *et al.*, 2003).

Plate 3.2 Aqualab Water Activity Meter

3.4. Proximate analysis of extruded product

3.4.1 Estimation of crude protein

Protein is the most essential nutrient present in many food crops. The major element present in the protein is nitrogen, which generally constitutes 16% of the total makeup. Determination of the nitrogen content is the easiest way to compute the crude proteins using Kjeldahl digestion tubes on Kjeldahl apparatus (plate 3.3). A finally ground extrudate sample powder of 0.2 g was taken into a digestion tube.

Digestion mixture is prepared by mixing potassium sulphate and copper sulphate in the ratio 5:1. Add 3 g of digestion mixture to 10 ml of concentrated sulphuric acid to the sample. The sample was digested in a digestion unit till it become colourless. Then the tubes were cooled and transferred to the distillation unit. 40 % NaOH solution was allowed into the tube. Liberated ammonium was absorbed in boric acid (4 %) solution containing mixed indicator (10 ml bromo cresol green and 7 ml of methyl red). The pink colour of the boric acid solution was turn into green and this was titrated against 0.1 N HCl. Until the pink colour was obtained. The percentage protein was obtained by using the following formula:

$$\text{Protein (\%)} = \frac{(\text{Titre value} - \text{Blank volume}) \text{X} \text{Normality of HCl X } 14.007 \text{X} 6.25 \text{X} 100}{\text{Weight of sample}}$$

Plate 3.3 Kjeldhals apparatus

3.4.2 Estimation of carbohydrate

Carbohydrate is first hydrolysed into simple sugars using dilute hydrochloric acid. In hot acidic medium glucose is dehydrated to hydroxymethyl furfural. This compound forms with anthrone, a green coloured product with an absorption maximum at 578 nm. Anthrone reagent was prepared by dissolving 200 mg anthrone in 100 ml of ice cold 95% sulphuric acid. Glucose solution was prepared by dissolving 100 mg in 100 ml water. Hydrolyse by keeping it in boiling water bath for 15 min with 5 ml of 2.5 N HCl and cool to room temperature. Neutralise it with solid sodium carbonate until the effervescence ceases. Make up the volume to 100 ml and centrifuge. Collect the supernatant and take 0.5 ml and 1 ml aliquots for analysis. Prepare the standards by taking 0, 0.2, 0.4, 0.6, 0.8, and 1 ml of the glucose solution. Make up the volume to 1 ml in all the test tubes. Then add 4 ml of anthrone reagent. Heat for 8 min in a boiling water bath. Cool rapidly and read the green to dark green colour at 578 nm on a spectrophotometer.

$$\text{Amount of carbohydrate present in 100 mg of the sample} = \frac{\text{mg of glucose X 100}}{\text{Volume of test sample}}$$

3.4.3 Estimation of Fat content

The crude fat of the flour samples was determined as per AOAC (2005, 920.85) by Soxhlet extraction method using SOCS – PLUS apparatus (make: Pelican Equipment, SCS–08, Chennai, India). Two gram of extrudate was weighed accurately and transferred to a thimble. The empty beaker weight was taken and all the beakers were loaded into the system. The acetone was poured into the beaker from the top and boiled for 30 min at 80°C. After the completion of process time, the temperature was doubled to 160°C for 15 – 20 min to collect the acetone. All the beakers with residue were dried in hot air oven maintained at 100°C for 1 hour, cooled in a desiccator and again weight was taken. The final weight of the beaker was noted down and fat content was estimated by using the following equation:

$$\text{Fat (\%)} = \frac{(W_2 - W_1) \times 100}{W}$$

Where,

W_1 = Initial weight of the beaker, g

W_2 = Final weight of the beaker, g

W = Weight of the sample taken, g

3.4.4 Energy content

The energy is any sample is the crucial parameter deciding the nutritive value. This can be computed from the available nutrient information like protein, carbohydrate and fat content using formula given by F. kanayake. *et al*, 1999.

Energy (KJ/100g) = (Protein X 16.7) + (Fat X 37.7) + (Carbohydrates X 16.7)

3.5 Engineering properties of extruded products

3.5.1 Colour characteristics

The overall objective of colour to the food is to make it appealing and recognizable. Colour is important to consumer as a means of identification, as a method of judging quality and for its basic aesthetic value and Colour of the extruded RTE products was measured using Hunter lab colour flex meter (made by: Hunter Associates Laboratory, Reston, Virginia, USA).

The colour was measured by using CIELAB scale at 10° observer at D_{65} illuminant. It works on the principle of focusing the light and measuring the energy reflected from the sample across the entire visible spectrum. The colour meter has filters that relay on "standard observation curves" which defined the amount of red yellow and blue colours. It provides reading in terms of L*, a* and b*. The luminance (L*) forms the vertical axis, which indicates light - dark spectrum with a range from 0 (black) to 100 (white). In the same way, a* indicates the green - red spectrum with a range of - 60 (green) to + 60 (red) and b* indicates the blue - yellow spectrum with a range from - 60 (blue) to + 60 (yellow) dimensions respectively (Ali *et al*. 2008).

A cylindrical glass sample cup (6.35 cm dia. x 4 cm deep) was placed at the light port (3.175 cm dia.). The instrument was initially calibrated with a black as well as with standard white plate.

Plate 3.4 Hunter Lab Colour Flex Meter

3.4.2 Texture analysis

Textural properties of hot extruded ready-to-eat expanded (*kurkure*type) products were studied using a Texture Analyzer (TA.XT texture analyser, Stable micro systems Ltd.).

The texture analyzer measures force, distance and time, thus providing three dimensional product analyses. Force may be measured against set distance and distance may be measured to achieve set of forces. Results may be read directly from the keyboard or transmitted to a printer or computer. The probe carrier contains a sensitive cell. For RTE extruded products the experiments were carried out by different tests that generated as plot of force (N) vs. time (s), from which texture values for extruded product were obtained. Three replications of each combination were taken for analysis. During the testing, the samples were held manually against the base plate and the different tests were conducted according to TA settings. The textural properties such as hardness were measured by using penetration test (Stable Micro Systems).

Plate 3.5 Texture analyser

TA settings

Mode: Measure Force in Compression

Option: Return to Start

Pre Text speed: 1.50mm/s

Test speed: 2 mm/s

Post Test speed: 10 mm/s

Distance (compression): 20 mm

Data Acquisition Rate: 400 pps

3.4.3 Sensory evaluation

Sensory evaluation is the scientific discipline used to evoke measures to analyze and interpret reactions to those characteristics of food as they are perceived by the senses of sight, smell, taste, touch and hearing. Sensory attribute of quality, guide the consumer in his selection of foods, also for determining the conformity of a food with established government or trade standard and food grade. A successful implementation of sensory evaluation program requires major components like proper laboratory facilities, sensory panels and rigorous training program (Reece, 1979). Since the extrudates from the twin screw extruder were bland in taste, they were first “prepared” like the commercial *kurkure*product before serving to sensory panel. The hot extruded RTE products were “prepared” by coating with commercial *masala*. The RTEproducts were toasted with 3 tsp of sunflower oil (per 100 g) and 2 tsp of *chat masala* as a flavouring agent. The prepared products were evaluated for sensory characteristics by a panel of 10 judges along with the commercially available product as a control.

SENSORY SCORE CARD FOR EXTRUDED SNACKS

Date:

Name of judge:

You are requested to assess the product in terms of general acceptability on a 9 point hedonic scale

Score system:

Like extremely 9

Like very much 8

Like moderately 7

Like slightly 6

Neither like nor dislike 5

Dislike slightly 4

Dislike moderately 3

Dislike very much 2

Dislike extremely 1

Characteristics	Sample code						
	A	B	C	D	E	F	G
Colour and appearance							
Texture							
Flavour							
Taste							
Crispiness							
Overall acceptable							

Comments Signature

Fig 3.1 Sensory Score card for the extruded product

3.6 Selection of the best hot extruded RTE, expandedproducts

Among the 6 combinations, screening was done, primarily based on sensory characteristics. The best judged product was the one which was of good taste, and overall acceptability.

RESULTS AND DISCUSSIONS

CHAPTER – IV

RESULT AND DISCUSSIONS

This chapter deals with the results and discussion of the experiments conducted on extrusion with the corn and pulse varieties (Mung bean and Bengal gram) blended in different proportions for developing hot extruded (RTE) products. The second phase of investigation was quality analysis of the selected extrudates with objective and subjective parameters.

4.1 Hot extrusion (RTE)

Optimization of feed moisture content, screw speed and final treatments were carried out based on previous studies and preliminary trials. The results obtained are presented and discussed in details under the sessions as given below.

4.2 Development of hot extruded RTE product

Based on earlier studies conducted by Seema *et al.,* (2016), a screw speed of 350rpm and feed moisture content of 14% were selected. The temperature considered was 140^{o} C.

4.3 Quality parameters of hot extruded RTE products

The quality parameters *viz*. physical and engineering properties of the hot extrudates were determined by standard laboratory procedures as mentioned in chapter III and their results are discussed.

4.3.1 Quality of the hot extrudates based on physical properties

Physical properties of the seven extrudates in terms of expansion ratio, bulk density, and water activity are discussed under the following headings.

4.3.1.1 Expansion ratio

Expansion is an important physical property of the developed snack food. Starch is the main component in cereals which plays a major role during expansion process (Kokini*et al.*, 1992). The expansion ratio of nutrient enriched starch based RTE products varied from 4.017 to 4.317 are given in Appendix A. The maximum expansion ratio (4.317) was observed for combination C_6 .Significant variation ($p<0.0001$) was noticed as regards expansion ratio for the seven combinations under consideration.

Combinations	Expansion ratio
Control	2.34
C_1	4.017
C_2	4.15
C_3	4.155
C_4	4.071
C_5	4.14
C_6	4.317

Table 4.1 Expansion ratio of the RTE product

The results showed that expansion increased with increasing corn content, this can be explained by the fact that when feed material with high percent corn (having more starch) results in increasing in starch gelatinization during extrusion thereby increases extrudate volume. This observation coincides with that of extruded product prepared using hard-to-cook beans and quality protein maize (Ruiz *et al.*, 2008).

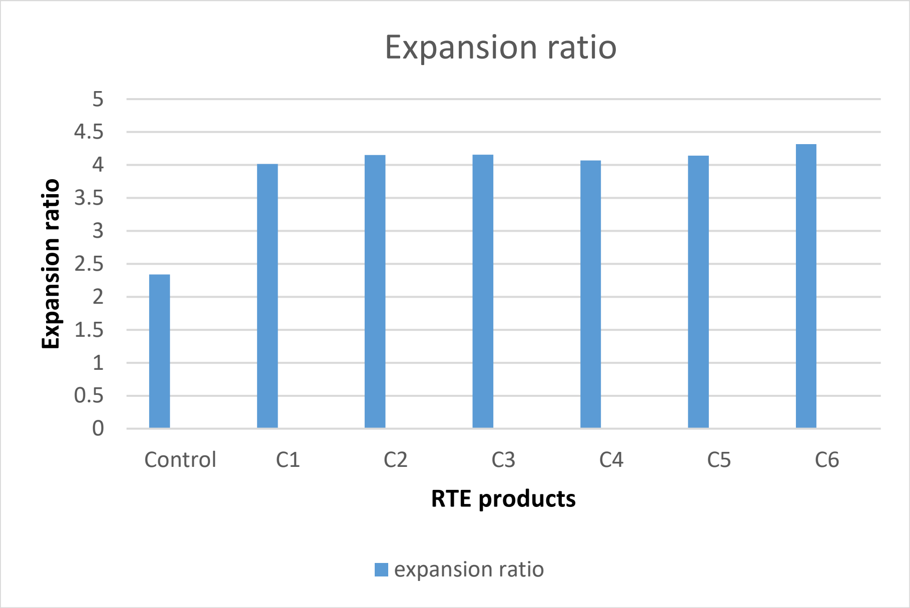

Fig 4.1 Expansion ratio of RTE product

4.3.1.2 Bulk density

Density is a major physical property of the extrudate product. Bulk density, which considers expansion in all direction ranged from 0.66 to 0.97 g/cm^3. It was observed that the minimum bulk density (0.66 g/cm^3) was observed for C_4 and maximum bulk density (0.97g/cm^3) was observed for C_1. Significant difference ($p<0.0001$) was noticed as regards bulk density and for the combinations under concern.

Combinations	Bulk Density (g/cm$^{3)}$
Control	0.56
C_1	0.97
C_2	0.88
C_3	0.87
C_4	0.66
C_5	0.92
C_6	0.73

Table 4.2 Bulk density of RTE product

Though higher bulkdensity indicated high mass per unit volume, it indicates more expansion during the extrusion process which is a desirable characteristics of the extruded product. More expansion leads to a better extruded product. On the other hand a very high bulk density relates in difficulties in packaging and product damage during transport. Therefore bulk density value 0.66 g/cm^3 for treatment C_4 can be considered optimum.

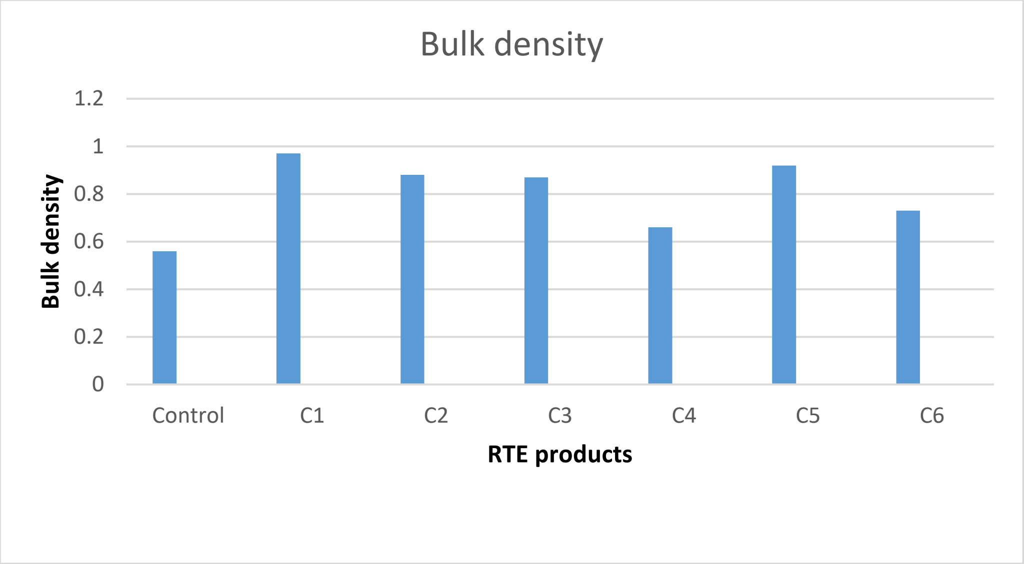

Fig 4.2 Bulk density of RTE products

4.3.1.3 True density

The effect of twin screw extruder barrel temperature and screw speed on the true density is presented in table.True density ranged from 0.97 to 1.04 g/cm^3 for different combinations. Among these combinations C_4 has the minimum true density (0.76 g/cm^3) and maximum bulk density is for combination C_5.

Combinations	True density (g/cm^3)
Control	0.6
C_1	1.03
C_2	1.02
C_3	0.9
C_4	0.76
C_5	1.02
C_6	0.97

Table 4.3 Tue density of RTE products

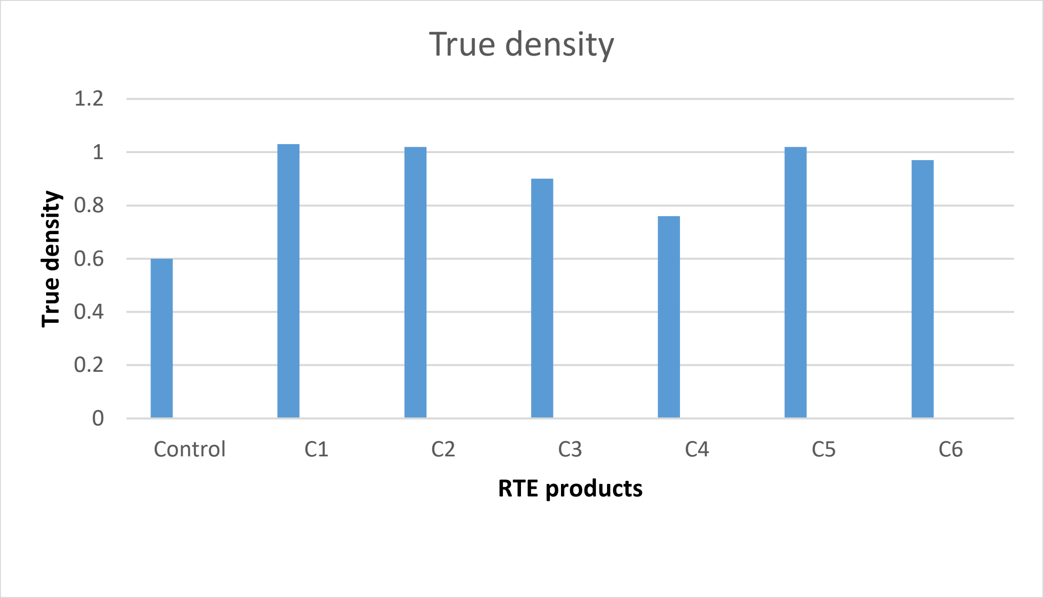

Fig 4.3 True density of RTE product

4.3.1.4 Water activity (a_w)

The water activities of the extrudates were determined by methodologies explained in 3.3.3. This property was used as a critical control point to correlate whether the products made were in safe level. The water activities of all combinations ranged from 0.504 to 0.547. The maximum a_w(0.547) was observed for C_1 combination whereas, minimum a_w(0.504) was observed for C_4 combination. Significant variations were noted with respect to a_w of each combinations ($p<0.05$)

Combinations	Water activity (a_w)
Control	0.32
C_1	0.547
C_2	0.528
C_3	0.510
C_4	0.504
C_5	0.510
C_6	0.515

Table 4.4 Water activity of RTE product

The results showed that water activities of all treatments were safe for storage at a feed moisture of 14 %.

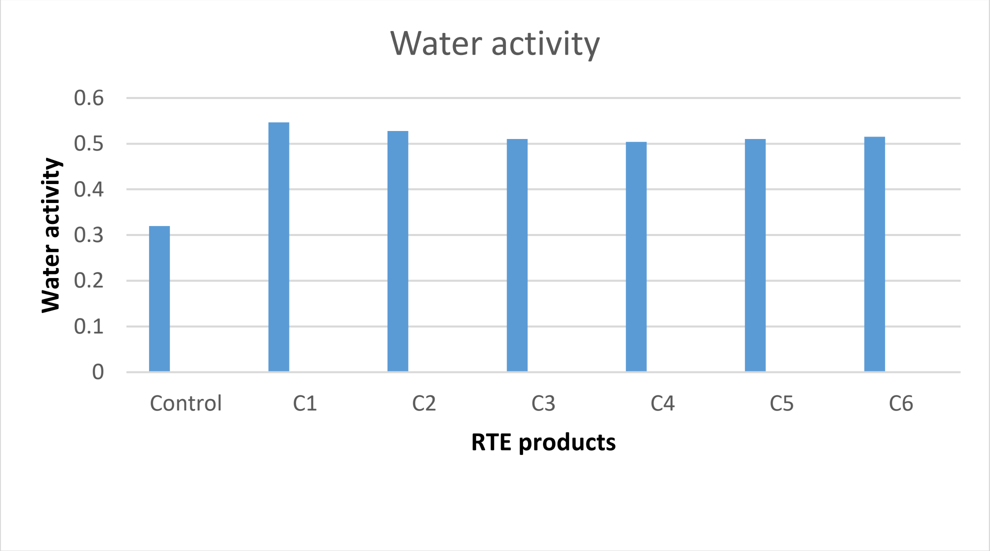

Fig 4.4 Water activity of RTE product

4.3.1.5 Protein analysis

Protein was less in case of C_1 which is 4.875 g and more in the combination C_4 having 7.128 g.The result showed significant variation with respect to each selected samples. The extrudates hardness was found to be strongly influenced by the protein content. Increased protein content produced a less expanded and more rigid network resulting in higher resistance to shear (Chaiyakul*et al*., 2009). It also confirmed that extrusion resulted in the regularity of nitrogen reduction by facilitating high process temperatures. Low amount of protein was due to the nitrogen losses in the course of extrusion by the formation of isopeptide bonds with simultaneous emission of ammonia (Kasprzak and Rzedzicki, 2008, Jhoe*et al*., 2009).

Composition	Protein (g)
Control	5.8
C_1	4.875
C_2	6.213
C_3	5.69
C_4	7.128
C_5	5.06
C_6	6.629

Table 4.5 Protein analysis of RTE product

4.3.1.6 Carbohydrate

Starch content was found maximum for combination C_4 (70.8 mg/100g) and low for combination C_5 (50 mg/100g). There are significant variation as regards starch contents with regard to different combination. This carbohydrate content was high in cereal based composition which also contributed good solubility index due to starch content. This was in confirmation to the results of Pawar*et al*.2009.

Combination	OD	Concentration (mg/100g)
Control	0.425	46
C_1	0.684	70.4
C_2	0.5	52
C_3	0.55	54
C_4	0.678	70.8
C_5	0.477	50
C_6	0.7	72

Table 4.6 Carbohydrate analysis of RTE product

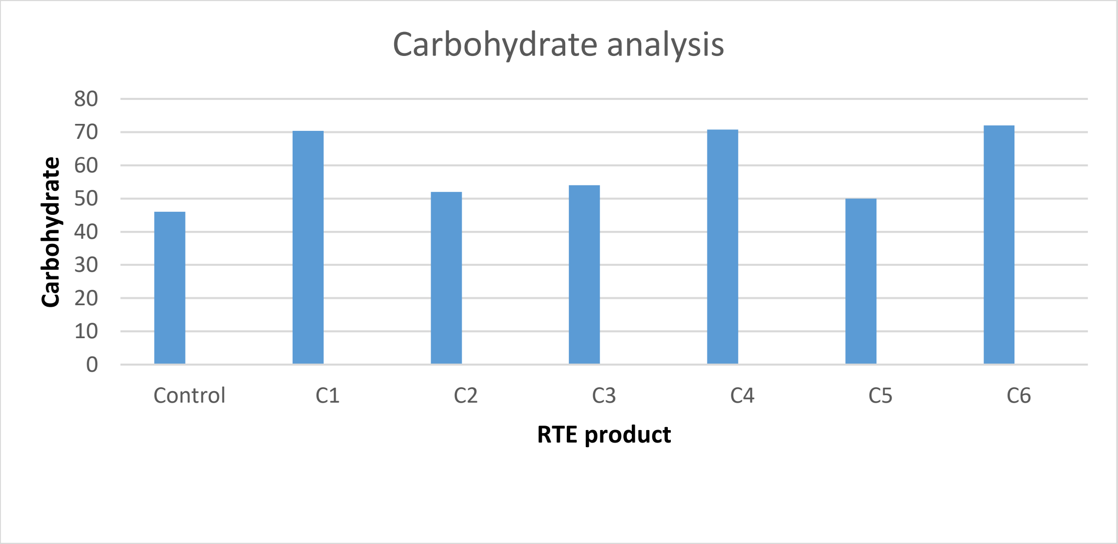

Fig 4.5 Carbohydrate analysis of RTE product

4.3.1.7 Fat

Fat wasfound maximum in combination C_3 (0.7 %) and minimum in combination C_4 (0.2 %). This variation in fat content during extrusion is caused by the formation of starch-lipid and protein-lipid complexes (Bhatnagar and Hanna, 1994)

Combination	Fat content(%)
Control	0.34
C_1	0.55
C_2	0.3
C_3	0.7
C_4	0.2
C_5	0.4
C_6	0.6

Table 4.7 Fat analysis of RTE product

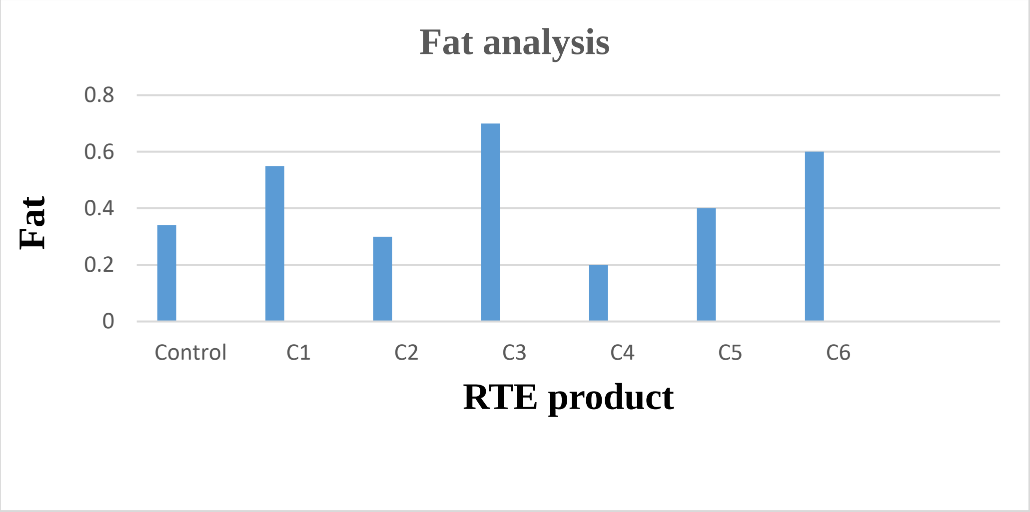

Fig 4.6 Fat analysis of RTE product

4.3.1.8 Energy content

From these proximate compositions, the total energy achieved by each samples was calculated with Atwar formula and found higher for C_6(1335.7243 KJ) and lower for C_1(862.4304 KJ).

Combination	Energy (KJ/100g)
Control	877.87
C_1	862.4305
C_2	983.4671
C_3	1023.213
C_4	1038.9376
C_5	934.582
C_6	1335.7243

Table 4.8 Energy content in the RTE product

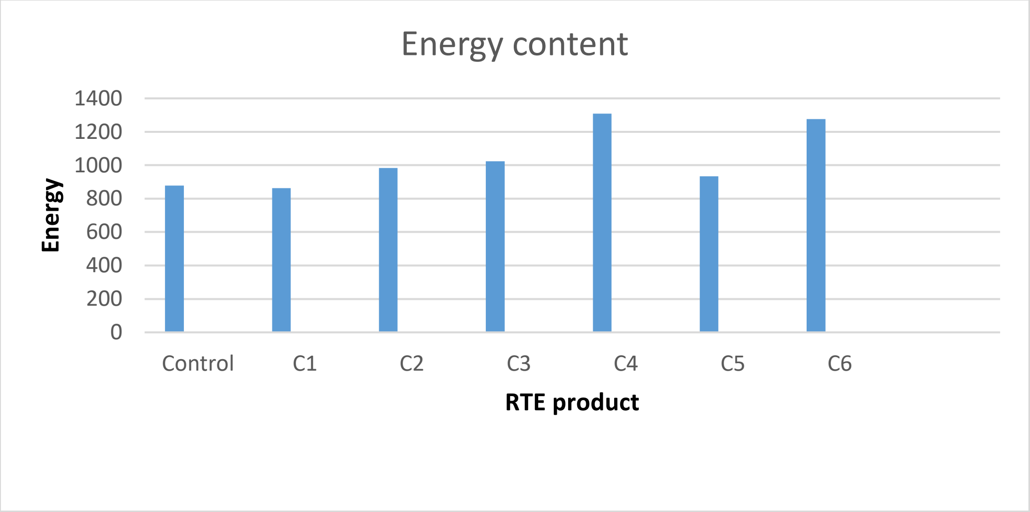

Fig 4.7 Energy content in the RTE product

4.4 Quality of the hot extrudates based on colour properties

The tri-stimulus colour values were calculated as per the methodologies discussed under 3.4.1. Significant variation ($p<0.0001$) was noticed as regard to L*, a* and b* values for the various combinations under concern.

4.4.1 Colour (L*value)

Colour is one of the most vital physical attributes of extrudate product. The maximum value for lightness is 100 indicating whiteness. Therefore, decrease in L**value indicates a decrease in whiteness. Colour of various combinations of extrudates varied from 61.49 to 73.08. The maximum colour L*(73.08) was observed for combination C_4 whereas, minimum colour L*(61.49) was observed for combination C_2.

4.4.2 Colour (a*value)

The *a** value for various combinations of extrudates varied from 5.61 to 13.16. The maximum colour a*(13.16) was observed for combination C_2, whereas, minimum colour a*(5.61) was observed for combination C_1.

4.4.3 Colour (b*value)

The b*value for various combinations of extrudates varied from 27.20 to 34.69. The maximum colour b*(34.69) was observed for combination C_5, whereas, minimum colour b*(27.20) was observed for combination C_4.

Combination	L* value	a* value	b* value
Control	63.66	14.84	39.60
C_1	70.35	5.61	28.83
C_2	61.49	13.16	29.31
C_3	70.90	5.75	32.56
C_4	73.08	5.63	27.20
C_5	64.32	13.01	34.69
C_6	72.58	6.94	34.68

Table 4.9 Colour characteristics of the RTE product

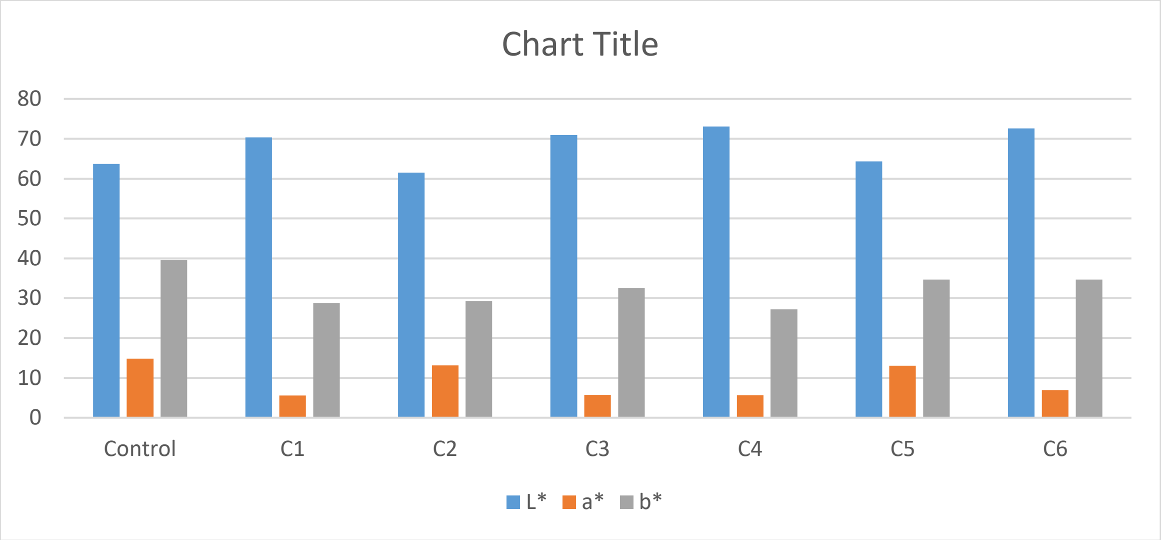

Fig 4.8 Colour charecteristics of the RTE product

4.5 Texture analysis

The textural properties of the extrudates were determined by measuring the peak force and breaking force by the methodologies described as per section 3.4.2. Textural properties are discussed in terms of toughness, shearing force. The maximum value of toughness and the crispiness is for combination C_1 (1605.94, 2516.3) and minimum for the combination C_5 (76.2.2, 1983.4) The results for these textural properties are tabulated in table 4.10.

Combinations	Toughness (gsec)	Shearing force (N-sec)
Control	783.56	2236.2
C_1	1605.94	2516.3
C_2	927.26	1956.9
C_3	846.77	2064.5
C_4	894.83	2145.8
C_5	762.2	1983.4
C_6	1196.4	2185.7

Table 4.10 Texture analysis of RTE product

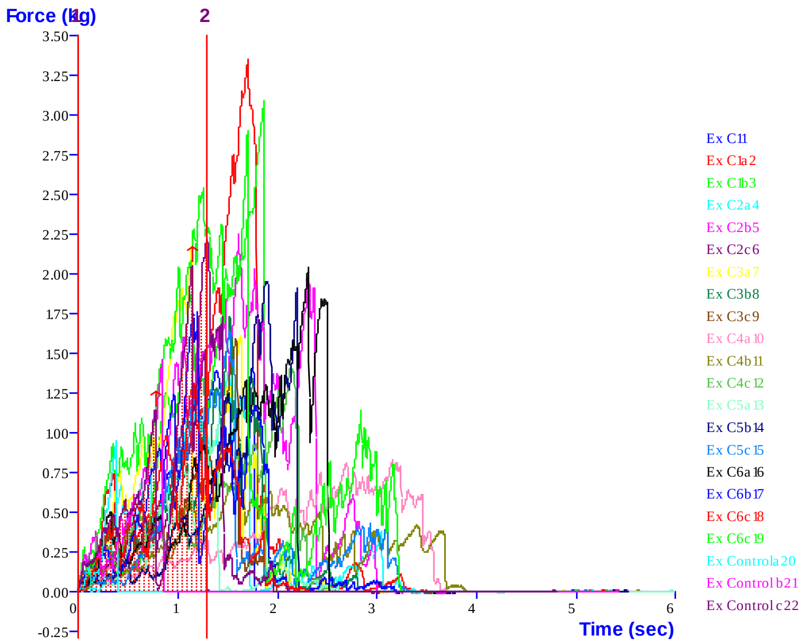

Fig 4.9 Texture analysis of RTE product

4.6 Sensory Evaluation of the extruded product

The success or failure of a new expanded product is directly related to sensory attributes,where texture place a major role (Iwe, 2000, Anton and Luciano, 2007). The extruded snacks that ranked first in the selected six extrudates with control was subjected to sensory evaluation by a panel of ten semi-trained members by nine pointhedonic scale. The sensory evaluation was carried out on the basis of colour and appearance, flavor, taste, crispiness and overall acceptability of the developed product. The sensory evaluation of the extruded product revealed that there were significant differences among the treatments for the organoleptic qualities. Considering the results of sensory evaluation, the best product was selected. The selected product was the one which was of good taste and overall acceptability. and were given in Table

Combination	Colour and appearance	Texture	Flavour	Taste	Crispiness	Overall acceptability
Control	7.50	8.02	8.9	8.8	8.5	8.34
C_1	7.83	7.81	8.14	8.00	7.23	7.80
C	6.25	8.23	7.65	7.68	7.82	7.52
C	7.02	7.61	7.53	7.23	7.34	7.34
C	8.7	8.89	8.80	8.69	8.61	8.73
C	8.36	7.88	8.78	8.44	8.32	8.35
C	7.97	7.69	8.24	8.38	8.4	8.13

Table 4.11 Mean sensory score card for RTE products

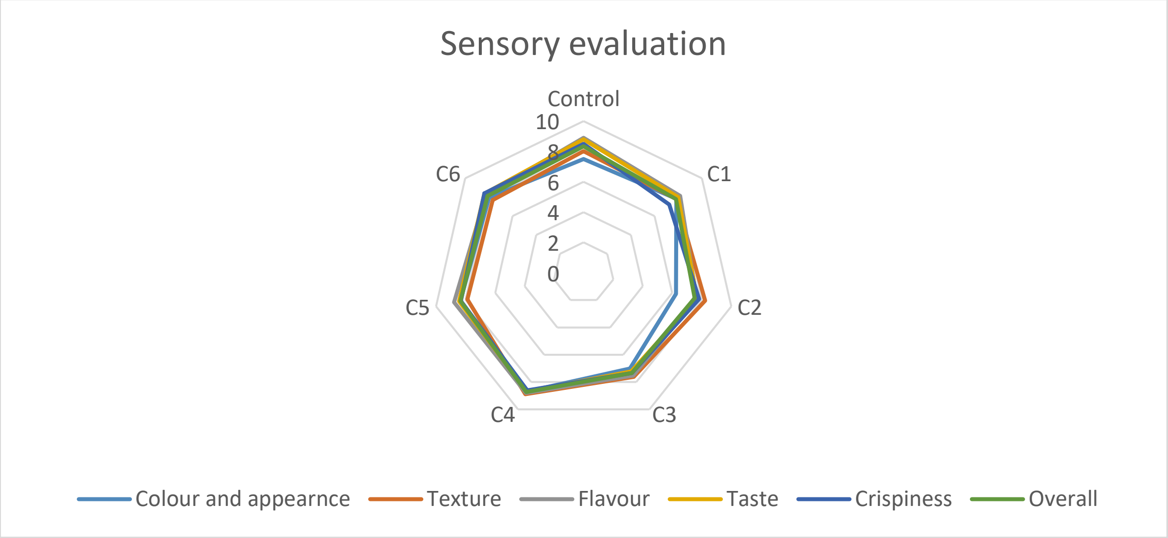

Fig 4.10 Sensory evaluation of RTE product

From this graph, it may be concluded that combination C_4 had the maximum score for all the characters viz. colour and appearance, texture, flavour, taste, crispiness and overall acceptability. Therefore the combination C_4 may be considered superior when compared to other treatments.

Plate 4.1 RTE products

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

Extrusion processing has become an important food process in the manufacture of pasta, ready-to-eat cereals, snacks, pet foods, and textured vegetable protein (TVP). The fast changing life style of the consumer demands convenience in terms of saving time and energy. Development of ready to eat snacks add convenience, serves labour and time, provides hygienic products of standard and uniform quality with enhanced shelf life. The extruder is a high temperature short time process which minimises losses in vitamins and amino acids. Colour, flavour and product shape and texture are also affected by the extrusion process. Extrusion has been widely applied in the production of nutritious food. The production and consumption of expanded ready-to-eat (RTE) products through extrusion cooking is notably increasing worldwide. So by keeping these points in view the research work entitled "Development and quality evaluation of nutrient enriched starch based RTE product" was undertaken in Department of Processing and Food Engineering, KCAET, Tavanur, Kerala.

Ready to eat extruded product were developed using corn flour, mung bean, Bengal gram, jackfruit seed powder, pseudostem, pumpkin, beetroot. A screw speed of 350rpm and feed moisture content of 14% were selected. The temperature considered was 140ºC and the different combinations we used are C_1 (Corn : Mung bean : Jackfruit seed : Pseudo stem), C_2 (Corn : Mung bean : Jackfruit seed : Beetroot), C3(Corn : Mungbean : Jackfruit seed : Pumpkin), C_4 (Corn : Bengal gram : Jackfruit seed : Pseudo stem), C_5 (Corn : Bengal gram : Jackfruit seed : Beetroot), C_6 (Corn : Bengal gram : Jackfruit seed : Pumpkin). Then the quality evaluation of the extruded product were done.

The quality parameters *viz*, physical properties (expansion ratio, bulk density, true density and water activity), functional properties(water absorption index and solubility index), engineering properties (colour, textural properties), proximate analysis (carbohydrate, protein, fat, energy content) for various RTE extruded products were determined. The extruded products were stored in a poly propylene covers.

The expansion ratio of nutrient enriched starch based RTE products varied from 4.017 to 4.317. The maximum expansion ratio (4.317) was observed for combination $C_{6.}$The results showed that expansion increased with increasing corn content, this can be explained by the fact that when feed material with high percent corn (having more starch) results in increasing in starch gelatinization during extrusion thereby increases extrudate volume. Bulk density, which considers expansion in all direction ranged from 0.66 to 0.97 g/cm^3. It was observed that the minimum bulk density (0.66 g/cm^3) was observed for C_4 and maximum bulk density (0.97g/cm^3) was observed for $C_{1.}$Though higher bulkdensity indicated high mass per unit volume, it indicates more expansion during the extrusion process which is a desirable characteristics of the extruded product. More expansion leads to a better extruded product. On the other hand a very high bulk density relates in difficulties in packaging and product damage during transport. Therefore bulk density value 0.66 g/cm^3 for treatment C_4 can be considered optimum.True density ranged from 0.97 to 1.04 g/cm^3 for different combinations. Among these combinations C_4 has the minimum true density (0.76 g/cm^3) and maximum bulk density is for combination C_5.The water activities of all combinations ranged from 0.504 to 0.547. The maximum a_w(0.547) was observed for C_1 combination whereas, minimum a_w(0.504) was observed for C_4 combination.

Protein was less in case of C_1 which is 4.875 g and more in the combination C_4 having 7.128g.Increased protein content produced a less expanded and more rigid network resulting in higher resistance to shear.It also confirmed that extrusion resulted in the regularity of nitrogen reduction by facilitating high process temperatures. Low amount of protein was due to the nitrogen losses in the course of extrusion by the formation of isopeptide bonds with simultaneous emission of ammonia.Carbohydrate content was found maximum for combination C_4 (70.8 mg/100g) and low for combination C_5 (50 mg/100g).. This carbohydrate content was high in cereal based composition which also contributed good solubility index due to starch content.Fat was found maximum in combination C_3 (0.7 %) and minimum in combination C_2(0.3 %). This variation in fat content during extrusion is caused by the formation of starch-lipid and protein-lipid complexes.It is found that energy content is higher for C_6(1335.7243 KJ) and lower for C_1(862.430 KJ).

Colour of various combinations of extrudates varied from 61.49 to 73.08. The maximum colour L*(73.08) was observed for combination C_4 whereas, minimum colour L*(61.49) was observed for combination C_2.The *a** value for various combinations of extrudates varied from 5.61 to 13.16. The maximum colour a*(13.16) was observed for combination C_2, whereas, minimum colour a*(5.61) was observed for combination C_1.The b*value for various combinations of extrudates varied from 27.20 to 34.69. The maximum colour b*(34.69) was observed for combination C_5, whereas, minimum colour b*(27.20) was observed for combination C_4. Textural properties are discussed in terms of toughness, shearing force. The maximum value of toughness (1605.94) and shearing force(2516.3) is for combination C_1 and the minimum value of toughness (762.2) and shearing force (1983.4) is for combination C_5.

Based on sensory evaluation C_4 had the maximum score for all the characters *viz.* colour and appearance, texture, flavour, taste, crispiness and overall acceptability. Therefore the combination C_4 may be considered superior when compared to other treatments.The extruded snacks that ranked first in the selected six extrudates with control was subjected to sensory evaluation by a panel of ten semi-trained members by nine point hedonic scale.The sensory evaluation of the extruded product revealed that there were significant differences among the treatments for the organoleptic qualities. Considering the results of sensory evaluation, the best product was selected.

The selection was based on maximum expansion and maximum colour value and crispiness.

REFERENCES

CHAPTER VI

REFERENCES

A.A. Anton& F. B. Luciano 2009. Instrumental Texture Evaluation Of Extruded Snack Foods:arevision of Food Science, Faculty of Agriculture & Food Sciences, University ofManitoba , *Winnipeg, , Canada*, MB, R3T 2N2

ltan, A.McCarthy, K.L.Maskan.,2008. Evaluation Of Snack Foods From Barley-Tomato Pomace Blends By Extrusion Processing, *New York*

Aneeshya, K.K.S., Sudheer, K.P., 2012. Development and quality evaluation ofextruded snack from starch based food products. Abdel-Gawad, A. S. (1993). Effect of domestic processing on oligosaccharide content ofsomedry legume seeds. Food Chemistry, 46(1), 25–31.

Anton, A.A., and Luciano, F.B. 2007. Instrumental texture evaluation of extruded snack foods. *CienicTecnol Aliment*. 5(4): 245-251.

Anton AA, Fulcher GR, Arntifield DS. Physical and nutritional impact of fortification of corn starch-based extruded snacks with common bean (*Phaseolus vulgaris* L.) flour: Effect of bean addition and extrusion cooking. Food Chem. 2009;113:989–996. doi: 10.1016/j.foodchem.2008.08.050.

AOAC. 1990. *Official Methods of Analysis*, 15th Ed., Association of Official Analytical Chemists, Washington, DC.

Berrios, J. De J. (2006). Extrusion cooking of legumes: Dry bean flours. In Heldman, D. R. (Ed.), Encyclopedia of agricultural, food, and biological engineering (pp. 1–8). London, England: Taylor & Francis Group.

Bhattacharya, M. and HANNA, M.A. 1987. Kinetics of starch gelatinization during extrusion cooking. J. Food Sci. *52*, 764–766.

Bhat R, Karim AA (2009) Exploring the nutritional potential of wild and underutilized legumes. Comp Rev Food Sci Food Safety 8:305-331.

Chang, J.Y., Chung, D.S., Seib, P.A., Flores, R.A., and Hanna, M.A. 2001. Physical properties of starch-based foams as affected by extrusion temperature and moisture content. *Int. J. Ind. Crops Prod*. 14: 23-30.

Chiang, B.-Y., & Johnson, J. A. (1977). Gelatinization of starch in extruded products. Cereal Chemistry, 54, 436–443

Choudhary, S., Choudhary, A.K and Sharma, O.P. 2011. Screening ofmungbean(Vigna radiata) genotypes to identify source of resistance to dry root rot. *Journal of Food Legumes*. 24: 117-119.*Engineering*.66:283-289

Deepika, B., Chitra, S., and Shakti, S. 2014. Development and quality evaluation of extruded fortified corn snack.

Devi. N. Lakshmi, Shobha, S., Tang , X., Shaur., Dogan, H and Alavi,S. 2013. Development of protein-Rich Sorghum-Based ExpandedSnacks Using Extrusion Technology. *International Journal of FoodProperties*.16: 263– 276.

Ding, Q.B., Ainsworth, P., Tucker, G., and Marson, M. 2005. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. *J. Food Eng*. 66: 283-289.

D J Nithya, K A S Bosco, M Saravanan, R J Mohan and K Alagusundaram 2015.Optimization of Process Variables for Extrusion of Rice – Bengal Gram Blends.Indian Institute of Crop Processing Technology, Thanjavur -613005, Tamil Nadu, India

J. De J. Berrios a, P. Morales b , M. Camara b , M.C. Sanchez-Mata b,2010.Carbohydrate composition of raw and extruded pulse flours.aUSDA, ARS, WRRC, Albany, California 94710, USA bDpto. Nutrición y Bromatología II, Bromatología, Fac. Farmacia, Universidad Complutense de Madrid, Madrid, Spain.

Kavya, R.M., Aparna, K., Lakshmi, D.N., Krishniah, N., Charanjit, K., and Nagamalleswari, Y. 2014. Development of extruded ready to eat snacks using corn, black gram, roots and tuber flour blends.

Mary Omwamba, Symon M. Mahungu(2014). Development of a Protein-Rich Ready-to-Eat Extruded Snack from a Composite Blend of Rice, Sorghum and Soybean Flour. Department of Dairy, Food Science & Technology, Egerton University, Egerton, Kenya.

Meng, X., Threinen, D., Hansen, M., and Driedger, D. 2010. Effects of extrusion conditions on system parameters and physical properties of a chickpea flour-based snack. *Food Res. Int*. 43: 650-658.

M. S. Abedin, M. M. Nuruddin, K. U. Ahmed, A. Hossain(2012).Nutritive composition of locally available jackfruit seeds (*Artocarpusheterophyllus*) in Bangladesh.Department of Biochemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

MKavya Reddy, AparnaKuna,N Lakshmi Devi, N. Krishnaiah& CharanjitKaur& Y. Nagamalleswar (2014).Development of extruded Ready –To-Eat (RTE) snacks using corn,blackgram,roots and tuber flour blends.Association of Food Scientists & Technologists (India) 2014

Onwulata, C.I. and Konstance, R.P. 2006. Extruded corn meal and whey protein concentrate: Effect of particle size. *J. Fd. Processing and Preservation*. 30: 475-487.

Onwulata, C.I., Smith, P.W., Konstance, R.P., and Holsinger, V.H. 2001. Incorporation of whey products in extruded corn, potato or rice Snacks. *Food Res. Int*. 34: 679-687..

Onwulata, C.I., Konstance, R.P., 2006. Extruded corn meal and whey proteinconcentrate: effect of particle size. J. Food Process. Preserv. 30, 475e487

Osman, K.T., Nalan, G., Kirsi., J., and Satu, K. 2017. Development of extruded shrimp-corn snack using response surface methodology.

Palazuelos, A., Morales, Z., and Bustos, M. 2006. Preparation of high-quality protein-based extruded pellets expanded by microwave oven. *Cereal Chem*. 83(4): 363-369.

P Bhattacharyya, U Ghosh, H Ganopadhyay and Raychaudhuri.(2005). Physico-chemical characterstics of extruded snacks prepared from rice (*oryzasativa*L),corn (*zea mays* L) and taro(*colocasiaesculenta*(L) Schott] by twin-screw extrusion.Department of food technology & Biochemical engineering ,JadavpurUniversity,Kolkata 700 032.

Reddy, N. R., Salunkhe, D. K., & Sharma, R. P. (1980). Flatulence in rats following ingestion of cooked and germinated black gram and a fermented product of black gram and rice blend. Journal of Food Science, 45(5), 1161–1164

Seema, B.R., Sudheer, K.P., 2016. Development and quality evaluation of millet fortified tuber based extruded RTE products.

Singh, D.S., Garg, S.K., Singh, M., and Kalpana, D. 2005. Optimization of processing parameters of soy-sorghum blends extrudates. *J. Agric. Eng*. 42(4): 42-49.

Thymi, S., Krokida, M.K., Pappa, A., and Maroulis, Z.B. 2005. Structural properties of extruded corn starch. *J. Food Eng*. 68: 519-526.

Wu, Rui, X., Li, W., Chen, X., Jiang, M., and Dong, M.,"Mung bean (Vignaradiata) as probiotic food through fermentation with Lactobacillus plantarum B1-6", LWT -Food Science and Technology, vol. 63, pp. 445-451, 2015

W. Liu, and Shen, Q., "Structure analysis of mung beanstarch from sour liquid processing and centrifugation",Journal of Food Engineering, vol. 79, pp.1310-1314, 2007.Martínez, M.M., Rosell, C.M., Gomez, M., 2014. Modification of wheat flour func-tionality and digestibility through different extrusion conditions. J. Food Eng.143, 74e79.

Yagci, S. and Gogus, F. 2008. Response surface methodology of physical and functional properties of extruded snack food developed from food by-products. *J.Food Eng*. 86: 122-132.

Yu, L., Ramaswamy, H.S., and Boye, J. 2013. Protein rich extruded products prepared from soy protein isolate-corn flour blends. *Food Sci. Technol.* 5(2): 485-497.

DEVELOPMENT AND QUALITY EVALUATION OF NUTRIENT ENRICHED RTE PRODUCT

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ABSTRACT

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In

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Faculty of Agricultural Engineering and Technology

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2019

ABSTRACT

As the eating patterns are changing day by day, snack foods play very important role in the diet of the modern consumer. Consumer appeal for ready-to-eat (RTE) products is forecast to grow rapidly as consumers demand convenient snacks with exciting sensory and textural properties. Extrusion technology has been used extensively in the production of cereal RTE snacks due to its ease of operation and ability to produce a variety of textures and shapes which appeal to consumers. So the present study was undertaken to develop ready to eat (RTE) expanded products from pulse varieties corn, mixed vegetables. The blends of six different combinations were extruded at temperature of 140ºC at a screw speed of 350 rpm and 14% feed moisture content. From these seven extruded product was evaluated for physical, colour and textural properties. The extruded products were stored in aluminium pouches and with nitrogen flushing. The physical parameters (expansion ratio, water activity, colour and textural properties), functional parameters (water absorption index and solubility index), engineering properties (colour, texture, sensory evaluation), proximate analysis (protein, carbohydrate, fat content) of RTE products were analysed. Based on sensory evaluation,Corn (60 %),Bengal gram (30%), Jackfuit seed powder(5%), Pseudostem powder(5%) RTE product was selected as the best combination out of all combinations under concern.