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Development of Ready to Eat Extruded Snacks from Blend of Under-Utilized Legumes and Millets

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Abstract

Extrusion cooking with composite flour blend is the most innovative concept to introduce nutrition rich ready to eat snacks into the market. The main objective focuses on developing snacks with under-utilized millets like Kodo millet and legumes like horse gram and Chick pea. Horse gram (36%) was subjected to seven different treatments like (soaking, sprouting, preconditioning) before blending into the mix containing Kodo millet (52%) and chick pea(12%). The process parameters were optimized at constant barrel temperature of 150^{0}C and constant screw speed of 275 rpm. The results were compared to the control containing no horse gram. The physio-chemical properties, nutritional composition and organoleptic properties of extrudates were analyzed. The results indicated that sprouted horse gram blended into composite flour produced extruded snacks which had more preference according to taste, expansion, sensory, color.

Keywords: Extrusion, Horse Gram, Extrudates, Composite Blend, treatments

INTRODUCTION

Extrusion cooking is the most recent and advanced technology to produce ready to eat snacks. Extrusion cooking involves high temperature and shorter time. [1] Extrusion cooking is an important processing technique in the food industry as it is considered to be an effective manufacturing process. Extrusion cooking utilizes high temperature, high pressure, and high force to produce products with low density, high expansion and unique texture. [2] In addition to the usual benefits of heat processing, extrusion offers the possibility of modifying the functional and rheological properties of food ingredients. [3] Extrusion cooking can be a continuous/batch process and produces less effluent.[4] The process variables such as feed rate, screw speed, barrel temperature and raw materials used for extrusion cooking play a greater influence on physicochemical properties of extrusion products.[5] The influence of processing conditions on product quality by extrusion of starch based legume blends has been widely investigated.[6] In this study a cost-effective protein source such as horse gram (*Macrotyloma uniflorum*), which is also known as poor man's pulse in Southern India. It is an excellent source of proteins (17.9–25.3%), carbohydrates (51.9–50.9%), essential amino acids, energy, and low content of lipid (0.58–2.06%), iron and molybdenum.[7] The use of dry seeds of horse gram as human food is limited due to its poor cooking quality, presence of high levels of enzyme inhibitors and haemagglutinins.[8] Utilization of horse gram can be maximized through an understanding of its physical and chemical components and through the implementation of diverse processing strategies to facilitate the development of economically viable alternative products .[9]

Kodo is one among the six other minor millets; kodo millet (*Paspalum scrobiculatum*) and barnyard millet together account for 10 % of total world millet production. Nutrient composition of kodo is comparable to other major cereals having 65–72 % carbohydrate, 8–9 % protein, 1–2 % fat, 2–3 % minerals, and 9 % fiber. Starch content (79 %) favors extrusion process in developing directly expanded snack.[10] The chickpeas (*Cicer arietinum*) contain moderately high protein (17–22 %), low fat (6.48 %), high available carbohydrate (50 %) and crude fiber contents of 3.82 % . [11]

Thus blending of kodo and chickpea enhances the carbohydrate-protein requirement and also serves as healthy alternative snack for kids and adults who requires essential nutrients for active living. [12] There is significant relationship between structural changes in the components of the feed which results in the changes in rheological properties such as extrudate expansion and texture in the extrudates. [13] In the present study horse gram(*Macrotyloma uniflorum*) ,Chick pea(*Cicer arietinum*), Kodo millet(*Paspatum serobiculatum*) were used to develop an extruded snack .Kodo has good textural properties and due to the incorporation of Kodo millet and chick pea with horse gram it becomes nutrient rich .The main objective of this study is to develop a nutritionally rich snack from under-utilized legumes and millets.

MATERIALS AND METHODS

Sample Preparation

Horse gram (*Macrotyloma uniflorum)*, Chick pea (*Cicer arietinum*), Kodo millet (*Paspatum serobiculatum*) were purchased from supermarkets (Rogers, Urapakkam, Tamilnadu) .Kodo millet and chick pea were cleaned and milled into flour from local flour mill. Horse gram was subjected to different treatments such as soaking, sprouting and preconditioning before milling into flour. Table 1 shows the assortment of samples with different treatments of horse gram .All the samples were kept at room temperature until use. After many experimental trial runs, the composition of flour blend was kept constant (Horse gram-36 %; Kodo millet-52 %; Chick pea-12 %).

Extrusion Cooking

Extrusion was performed in a laboratory scale twin screw extruder (M/S. BTPL,Kolkata, India) This counter rotating twin screw extruder was used for extrusion cooking of Kodo millet, and chick pea flour with differently treated horse gram flour. The extruder had self-wiping system for easy cleaning of the machine (inching).Extruded snacks were prepared by optimizing the process parameters .After many experimental trial runs, barrel temperature was kept constant at 150^0C and screw speed was set at 275 rpm. Feeding rate was kept constant throughout the experiments. The product extrudates were stored in polyethylene bags at room temperature and used for further analysis.

Analysis of Physical Properties

Bulk Density. Bulk density of extrudate is important parameter in the production of ready to eat food products and also in designing their packaging requirement. The diameter and length of the extrudates were measured using Vernier caliper. Bulk density was calculated from mass and volume of the extrudate as given in following equation. [14]

$$Bulk\ Density\ (g/cm^3) = \frac{4 * M}{\pi \times D^2 \times L} \quad (1)$$

Where M-mass (gm) ; D-Diameter of extrudate (cm) ; L-Length of extrudate (cm)

Expansion Ratio: This index describes the degree of puffing undergone by the sample as it exits the extruder. Expansion of extrudate of is mainly due to sudden change in state of high pressure to atmospheric pressure. This pressure drop causes a flash-off of internal moisture and water vapor pressure, which is nucleated to form a bubble in molten extrudate, which results in expansion of melt. [15] Expansion ratio measured as the ratio of the cross-sectional area of the dried cylindrical extrudate to that of the die as shown in the equation 2. The diameter of the extrudate was determined by Vernier calipers.

$$Expansion\ Ratio = \frac{(Diameter\ of\ extrudate)^2}{(Diameter\ of\ die)^2} \quad (2)$$

Color Analysis: A color co-ordinate of extruded product was measured under Hunter calorimeter (Hunter associates Laboratory, USA). It represents the color in L*, a* and b* value. Degree of lightness or darkness of the samples was represented by "L*" value, "a "represents redness (+) to greenness (-) and yellowness (+) to blueness (-) represented by "b*" value on hunter scale. The apparatus was previously calibrated with standard white and black tile. Color (L*, a*, b* values) of the extrudate samples were determined* indicates the lightness and extends from 0 (black) to 100 (white). The color difference calculated by following equation (3)

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (3)$$

Where $\Delta L=L^*-L_\circ^*$; $\Delta a= a^*-a_\circ^*$; $\Delta b=b^*-b_\circ^*$

*Water absorption index (WAI) and Water solubility index (WSI):*Water absorption index (gelatinization index) has been generally attributed to the dispersion of starch in excess water, and the dispersion is influenced by the degree of gelatinization and extrusion-induced fragmentation of starch granules. Water solubility index measures the degree of starch conversion during which soluble polysaccharide released from starch. [16] Water absorption index and water solubility index refers to water hydration capabilities of the extruded product. WAI and WSI are calculated from following (4) and (5) equation.

$$WAI\ (g/g) = \frac{Weight\ gain\ of\ gel}{Dry\ weight\ of\ extrudate} \quad (4)$$

$$WSI = \frac{Weight\ of\ dry\ solids\ in\ supernatant}{Dry\ weight\ of\ extrudate} \times 100 \quad (5)$$

Textural Analysis

There is rapid flashing of stream when extrudate moves from a region of high pressure extruder to atmospheric pressure shall cause water to evaporate. At high temperature, the blend melts at die aperture forming the characteristic texture of snacks. The rheological properties of melt dependent on formulation, temperature, barrel moisture, screw speed, shear forces, die design Hardness is directly proportional to moisture and inversely proportional to extrudate expansion. Hardness of product depends on frictional heat and the residence time of the product. Mechanical properties of the extrudates were determined by a crushing method using a TA – XT2 texture analyzer (Stable Micro Systems Ltd , UK) equipped with a 500 kg load cell. An extrudate 1cm long was compressed with a probe SMS – P/75mm diameter at a crosshead speed 5 mm/sec to 3 mm of 90% of diameter of the extrudate. [17] It was advisable to condition the extrudates at warm temperature and low relative humidity, to remove the effect of moisture sorption during storage or between the times it takes from extrusion to texture analysis. [18] The compression generates a curve with the force over distance. The highest first peak value was recorded as this value indicates the first rapture of snack at one point and this value of force corresponds for hardness.

Microstructural Analysis: Scanning electron microscope was used to view extrudate in three dimensions and to determine the shape and surface of extrudate. Scanning electron microscope was used to get image of Cross section of extrudates. A beam of electrons was made to pass through the extrudates coated with a layer of gold which aides electron penetration, thus scanning the extrudates. SEM investigation includes study i.e. macroscopic, microscopic, evaluation of physicochemical parameters and phytochemical screening. [19]

Moisture Analysis: Moisture of feed and Extrudate was calculated by hot oven method(AOAC method). [20] Moisture retention was studied accordingly to AOAC method. [21] Moisture Retention studies is to analyze the amount of moisture in the product extrudates after extrusion and calculated from following equation (6)

$$Moisture\ Retention(\%) = \frac{Product\ Moisture}{Feed\ Moisture} \times 100 \quad (6)$$

Composition Analysis

Total Ash: Ash content was determined according to the AOAC. [22] 5g of sample was ignited at 550^0C for 3 hours in

a muffle furnace and Total ash was calculated from equation (7).

$$Total\ ash\ content(\%\ db) = \frac{Weight\ of\ the\ ash}{weight\ of\ the\ sample} \times 100 \quad (7)$$

Protein Estimation: The amount of protein was estimated in the given samples by Lowry's method. [23] Lowry method is extensively used for determination of protein in pulses and cereals.

Total Sugar: The content of total sugar was measured according to the Phenol-H2SO4 method. [24] Samples (1.0 g) were extracted by stirring them at room temperature in 10 mL of an ethanol-water (70:30 v/v).They were centrifuged at 3000 rpm for 20 minutes. The reaction mixture was composed of 1 mL of sample solution, 1 mL of 5% phenol solution and 5 mL of concentrated sulfuric acid. The absorbance was read at 550 nm after 15 min of incubation at room temperature. D-glucose was used as the standard.

Total phenols: The amount of phenolic compounds in the extruded snacks was calculated with Folin- Ciocalteu reagent. [24] 0.5g of sample was weighed and methanol was added to sample extract (80% methanol) followed by 2.5 of 10 fold dilute Folin–Ciocalteu reagent and 2.0 ml of 7.5% sodium carbonate solution were added. The mixture was allowed to stand for 30 min at room temperature and absorption was measured at 760 nm against a gallic acid which is used as standard. [25]

*Fourier Transform Infra-red Spectrometry:*IR spectroscopy is a powerful technique which provides fingerprint information on the chemical composition of the extrudates giving information regarding the functional groups at particular wave number (reciprocal of wavelength).Fourier Transform (FT), radiant power data is recorded as a function of time. This study has wide applicability in structure elucidation, which are either synthesized chemically or of natural origin. Fourier transform infrared spectroscopy (FT-IR) spectra were recorded using a FTIR-Bruker Equinox 55 for mid and nearIR regions, with a spectral range of 25–30 cm^{-1}. The samples were mixed with KBr and compressed on tablets. [26] They were measured in a range of frequency from 4000 cm^{-1} to 400 $cm^{-1.}$

Sensory evaluation: Organoleptic properties of the extrudates were evaluated with 9 point hedonic scale. Evaluation was carried out among different age groups ranging from 20 years to 60 years. Four to five people were carefully selected in the age groups of 20-30; 30-40; 40-50; 50-60 years. Results of sensory evaluation were recorded in 9 point hedonic scale with Like Extremely rated at 9 and Dislike Extremely rated at 1.

Statistical Analysis : The data obtained were analyzed statistically by Minitab Express(16 th edition) .For each parameter, Analysis of variance was carried out to calculate the mean values. All the values at $p \leq 0.05$ significance level and post hoc tests were run by Tukey test .

RESULTS AND DISCUSSION

Physical Properties of extrudates

The feed rate, temperature, screw speed and die speed were kept constant throughout the experiments. The effects of composite flour on physical properties of Extrudates were studied and results are discussed.

Bulk Density and Expansion Ratio: Bulk density of extrudate is important parameter in the production of expanded food products and also in relation to their ability to float or sink when poured into water and their packaging requirement. Bulk density considers expansion in all directions. Bulk density was calculated from mass and volume of the extrudate. [27] Expansion ratio and bulk density of the extrudates developed from composite flour blend containing seven differently treated horse gram varied significantly ($P<0.05$). Optimum blend composition when subjected to favorable moisture and temperature might have contributed to higher Expansion ratio. Similar results have been obtained by Chakraborty S.K et al in millet and legume extruded snacks. [28] Expansion is a function of viscosity and elasticity of dough governed by ratio of starch, protein and fiber. Water acts as a plasticizer and binds with starch and fiber to undergo transition during extrusion, thus facilitating the deformation of the mixture and influence expansion. [29]

The higher bulk density may be due to the presence of more crude fiber in the composite flour sample. Similar types of results were observed by Singh[30] and Desphande[31]. Bulk density has been linked with the expansion ratio in describing the degree of puffing in extrudate. At high moisture levels, the bulk density is also high. This is because the extrusion cooking is not enough to cause vaporization of the moisture, leading to retention of moisture in the extrudates.

Expansion ratio describes the degree of puffing undergone by the sample as it exits the extruder. Expansion of extrudate of is mainly due to sudden change in state of high pressure to atmospheric pressure. This pressure drop causes a flash-off of internal moisture and water vapor pressure, which is nucleated to form a bubble in molten extrudate, which results in expansion of melt. Expansion ratio is measured as the ratio of the cross-sectional area of the dried cylindrical extrudate to that of the die. The expansion ratio increases with decrease in feed moisture content and increase in screw speed and barrel temperature. Increased feed moisture leads to a sharp decrease in the expansion of extrudate. [32] Change in the feed moisture content owing to different treatments of horse gram significantly vary ($P<0.05$) the expansion ratio of all the extrudates as given in Table 2. Increasing the feed moisture content and screw speed resulted in a substantial decrease in expansion ratio. [33] Increase in barrel temperature resulted in extrudate with higher expansion, increasing in screw speed resulted in higher expansion and increasing level of moisture resulted in lower expansion. The bulk density of all extrudates is illustrated in Figure 1.

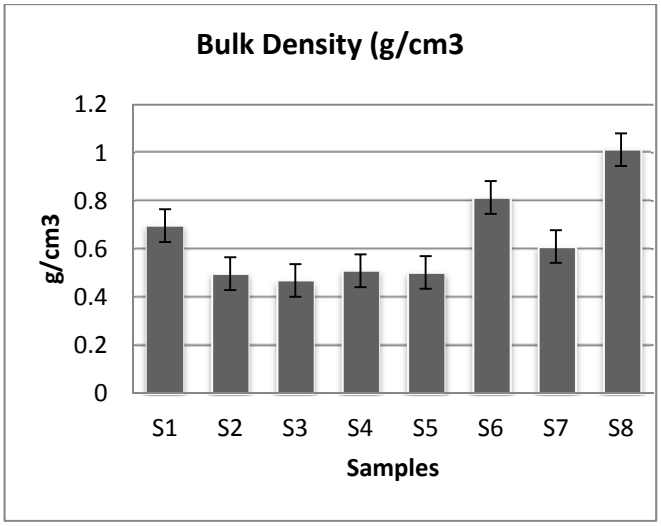

Figure 1: Bulk Density of various samples

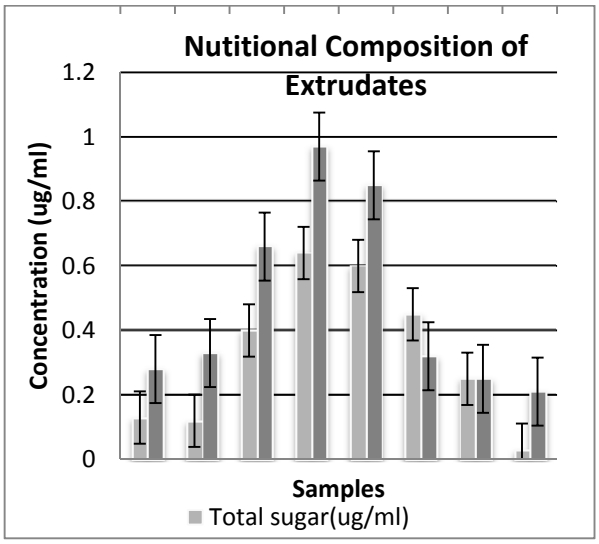

Figure 2: Nutritional Composition of extrudates

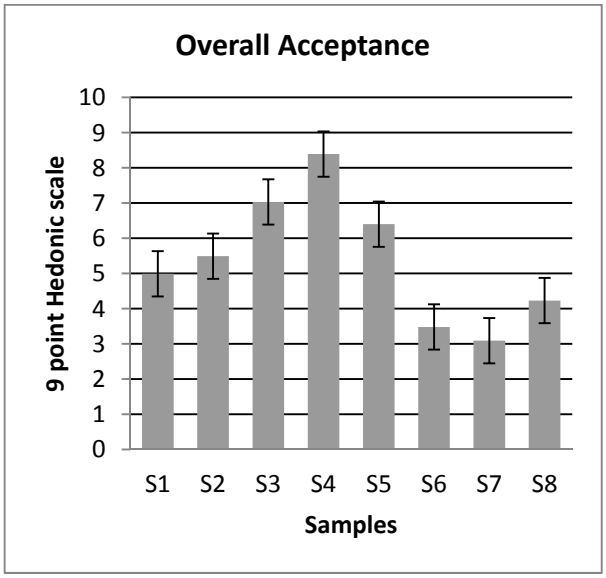

Figure 3: Overall acceptability of extruded snacks made from different samples.

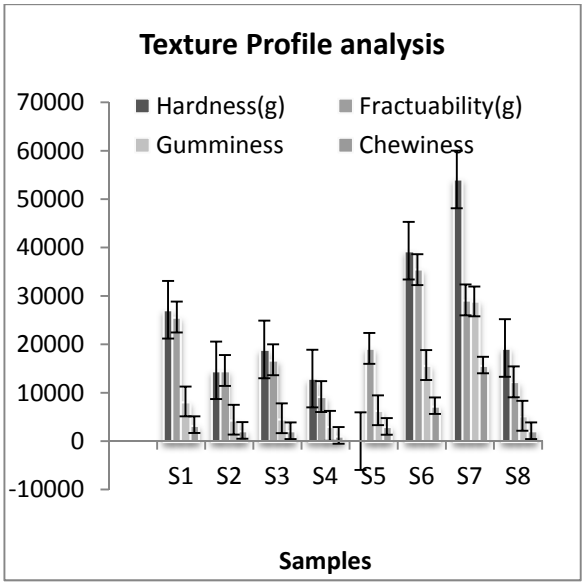

Figure 4: Texture profile Analysis of extrudates

Color Analysis: Color changes in the extrudates correlates to degree of browning reactions such as caramelization, Maillard reaction, degree of cooking and pigment degradation that take place during the extrusion process. [34] Lower L-value are an indicative of heat employed during extrusion that leads to maillard reactions which produce the brown pigments .These pigments also give distinct aroma, taste and color of final products .The pigmentation are results of many factors which includes temperature of extrusion, concentration of feed , reaction time and water activity . There was a significant change in color parameters ($p<0.05$) and L-values obtained at from extrudates produced from flour blends containing different treated horse gram varied from 69.64±0.04 to 50.44±0.01 .L values was highest in extrudates prepared from blend containing sprouted ,cooked horse gram and least in extrudates prepared from blend containing preconditioned horse gram at 4^0C .The difference in the color characteristics of puffing of extruded snacks was dependent on their treatments of horse gram used in different composite blends.

Water Absorption index (WAI) and Water Solubility Index (WSI): The enhanced ability of flour to absorb and retain water may help to improve binding of the structure, enhance flavor retention, improve mouth feel and reduce moisture and fat losses of food products. [35] Water absorption index and water solubility index refers to the interaction of extruded products with water. Water absorption index and water solubility index refers to the degree of gelatinization of starch during extrusion process. WAI is an index of swelling behavior of starch component and is indicative of hydrolytic breakdown of starch as well as protein denaturation and complex macro molecular formulation. [36] There was significant increase ($p<0.05$) in WAI and WSI in all blend formulations, irrespective of variable extrusion conditions. Increased WAI as a result of high damaged starch is a common phenomenon observed

during extrusion processing as reported by Martinez et al.,2014. [37]

WSI is indication of starch breakdown or dextrinization. Extrusion caused significant increase ($p<0.05$) in WSI in the extrudates prepared from composite flour blends irrespective of the different treatments to the horse gram. The values ranged from 20% -50% for all extrudates. Amongst all, extrudates produced from composite flour blend containing soaked horse gram showed optimum WSI and its corresponding WAI is lesser. This could be probably due to optimum moisture content which favored high dextrinization or starch melting that prevailed over the gelatinization phenomenon. [38] Water solubility index was found to be high for flour blend containing sprouted horse gram sample and Water solubility index was found to be higher in for flour blend containing soaked horse gram and refers to its digestibility.

Mechanical Properties of extrudates: Extrusion cooking of differently treated horse gram produced extrudates with varied texture. The amount of moisture in the feed also plays an important role in influencing the texture of the final product. Hardness is proportional to the amount of moisture in the sample. The texture of the extrudate is a very essential for evaluation of physical property for ready to eat snack. It largely depends on the composition and nature of the raw material of the mix used for extrusion. The ingredient composition and moisture content of the mix are the main factors that affect the texture of the final extrudate. The extruded materials tend to be highly hygroscopic and hence their texture gets affected if they are exposed to humid atmosphere. This property is important to differentiate the property of extrudates. [15]

Hardness is defined as the force required to compress a substance between the molar teeth (in the case of solids) or between the tongue and palate in the case of semisolids. [39] The substance is compressed to a given deformation or penetration, which is designated as soft, firm or hard. Texture Profile analysis of extruded snacks is especially required for snack foods, where crunchiness is a desirable attribute (Figure 4). A complete texture evaluation includes springiness, gumminess, Fractuability, cohesiveness, hardness, chewiness and mechanical properties of foods. [40] The degree of expansion determines the extrudates structure and consequently its texture. Extrudate expansion has been reported to be most depended on material moisture content and extrusion temperature.

The results obtained from statistical data reaffirms that there is a significant increase ($P<0.05$) in hardness with respect to moisture as given in table 3. The difference in the texture characteristics of puffing of extruded snacks was dependent on their treatments of horse gram used in different composite blends.

The mean scores of texture evaluation showed that all the extruded products prepared from composite flours were within the acceptable range .The extruded product prepared from composite flour containing sprouted horse gram had significant increase in appearance and decrease of hardness. It was revealed from the scores of the overall acceptability that the coarse millet grains and pulses can be successfully made into commercial product with acceptable textural characteristics. [27]

Nutritional Analysis

The amount of protein was estimated in the given samples by Lowry's method. Lowry method is extensively used for determination of protein in pulses and cereals. The results of the nutritional composition are illustrated in Figure 2. The protein content of extrudates ranged from 970ug/ml to 210ug/ml. It was apparent from the data, that treatment of horse gram in the flour blend causes significant reduction in protein content, irrespective in the blend formulation .There was significant difference ($p<0.05$) decrease in protein content is due to heat induced changes leading to transamination and deamination reactions and hence reduction in amino acids. [41] Gelatinization during extrusion processing may also cause reduction in protein content. Among the extrudates produced from flour containing sprouted horse gram (970ug/ml) has highest amount of protein followed by sprouted ,cooked horse gram (850ug/ml) and the least amount of protein was observed in control sample (210ug/ml) which contains no horse gram. Total sugar content is found to be highest in extrudates produced from flour blend containing sprouted horse gram and sprouted cooked samples and the least found in control which does not contain horse gram.

FTIR-Fourier transform infrared spectroscopy

IR spectroscopy is a powerful technique which provides finger printing formation on the chemical composition of the extrudates giving information regarding the functional groups at particular wave number (reciprocal of wavelength). The various functional groups present in the extrudates which appearing in form of bands due to molecular vibrations. [42]

The decrease in intensity of the broad band located between the frequency ranges of 3300cm^{-1} to 2300 cm^{-1} corresponds to the stretching vibration (O–H) of water molecules in the flour blend and is indicative of the dehydration resulted at a consequence of extrusion cooking. On the other hand, the peaks at 2950 cm^{-1} and 2400 cm^{-1} are associated with asymmetric and symmetric stretching modes of CH2.In the fingerprint region (800–1800 cm^{-1}) the peak at 1745 cm^{-1} appears due to the stretching of carboxylic group (C=O).

Microstructural Analysis

Scanning electron microscope was used to get image of Cross section of Optimized extrudates. SEM investigation includes study macroscopic, microscopy, evaluation of physicochemical parameters and phytochemical screening. Microstructure analysis performed by SEM revealed that extruded samples had porous, open-celled structures, degree of gelatinization of different treated horse gram in the composite flour blend . [31]

For the extrudates produced from sprouted horse gram (Figure 5) , maximum damage and breaking in continuous symmetrical structure is observed. Starch granules of varying sizes were observed on the cross section surface of extrudates produced from flour blends containing dry and

preconditioned horse gram. It is found to be rough, irregular and full of holes as thus confirming lesser degree of starch breakdown. While in extrudates produced from soaked horse gram starch granules are more gelatinized with minimal pores. In the extrudates produced from sprouted horse gram, starch granules within the extrudates appear to be slightly swollen and irregular in size and shape, perhaps indicating the level of gelatinization during the extrusion process .The results is in agreement with the results of the damage of starch molecules increases with increase in temperature . [28] The absence of symmetrical structure of starch granules in all figures indicates the complete gelatinization of starch during extrusion process. [43]

Microstructure analysis performed by SEM revealed that extruded samples had porous, open-celled structures. For the sprouted horse gram, SEM picture of extrudates shows maximum damage and breaking in continuous symmetrical structure. Fig.5 shows the damage of starch molecules which takes place during extrusion process. The extruded product had large no. of flattened and sheared granules. The results are in agreement with the results of Bhattacharya.[17] The damage of starch molecules increases with increase in temperature. The absence of symmetrical structure of starch granules in all figures indicates the complete gelatinization of starch during extrusion process. Microstructural studies reveals that the surface morphology of extrudates was also affected and the structure of starch molecules converted into sheared granules during extrusion process . [19]

Sensory Characteristics

Evaluation was carried out among different age groups ranging from 20 years to 60 years. Four to five people were carefully selected in the age groups of 20-30; 30-40; 40-50; 50-60 years. Evaluation of organoleptic characteristics of the extrudates such as appearance, color, taste, flavor, texture and overall acceptability were done with 9 point hedonic scale. Table 4 contains the ANOVA Analysis of Variance results for fitted models for overall acceptance for the final extruded product. The results are Significant at $P < 0.05$, DF: degrees of freedom. The mean scores of sensory evaluation showed that all the extruded products prepared from composite flours were within the acceptable range. The extruded product prepared from composite flour containing sprouted horse gram had significantly better appearance, color flavor, texture, taste, and overall acceptability as shown in Figure 3. It was revealed from the scores of the overall acceptability that the coarse millet grains and pulses can be successfully made into commercial product with acceptable sensory characteristics.

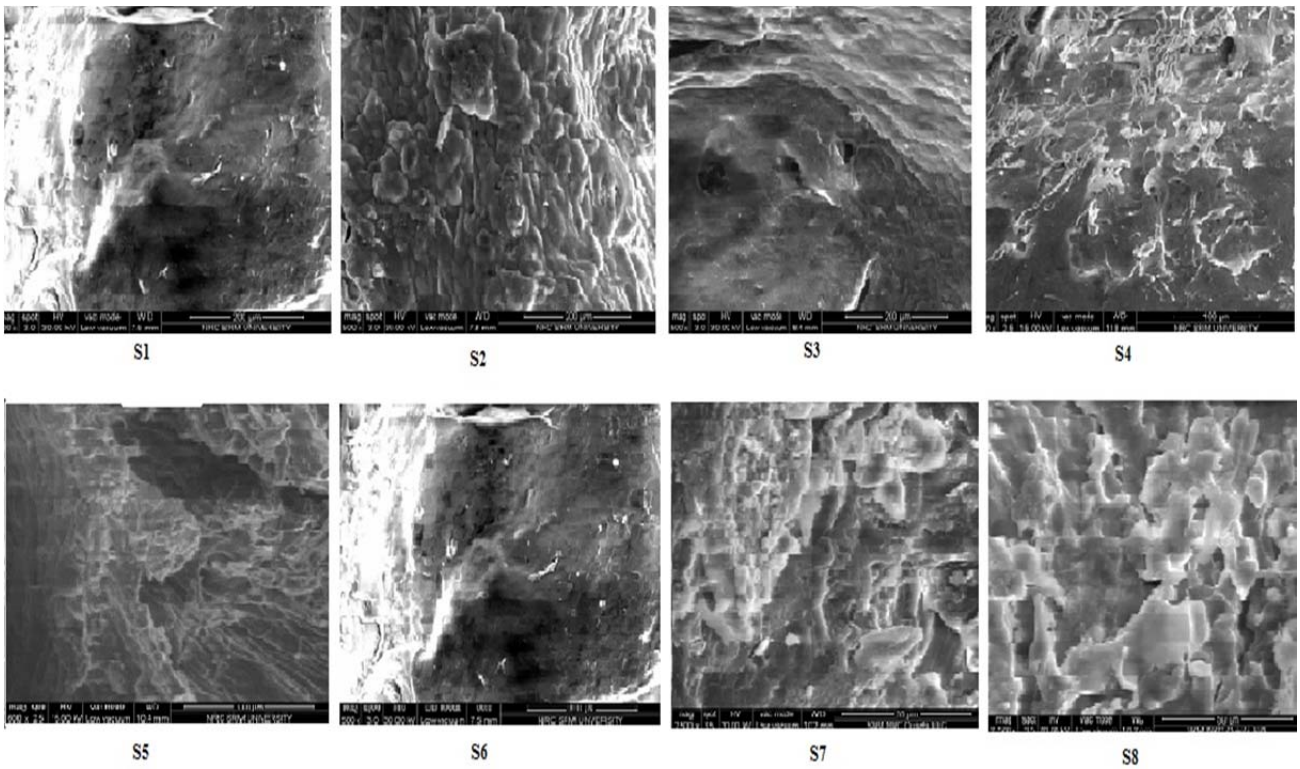

Figure 5: Image of cross section of extrudates obtained from scanning electron microscope.

Table 1: Assortment of Samples with differently treated horse gram.

Sample No	Varied treated Horse Gram in different samples
S1	Dry Horse gram
S2	Soaked dried Horse gram(4hrs)
S3	Soaked dried Horse gram(overnight)
S4	Sprouted and dried Horse gram
S5	Sprouted ,cooked dried Horse gram
S6	Preconditioned blend (18hrs 4^0C)
S7	Preconditioned blend (18hrs Room temperature)
S8 (Control)	Without Horse gram

Table 2: ANOVA Analysis of Variance results for fitted models.

	Source	DF	Adj SS	Adj MS	F-Value	P-Value
Bulk Density	Regression	2	2.87158	1.43579	29.49	0.0017*
	Error	5	0.24341	0.04868		
	Total	7	3.11499			
Expansion Ratio	Regression	1	0.086536	0.086536	3.25	0.0217*
	Error	6	0.159949	0.026658		
	Total	7	0.246485			

*Significant at P < 0.05, df: degrees of freedom.

Table 3: ANOVA Analysis of Variance results for fitted models.

	Source	DF	Adj SS	Adj MS	F-Value	P-Value
Overall acceptance	Regression	2	2.87158	1.43579	29.49	0.0017*
	Error	5	0.24341	0.04868		
	Total	7	3.11499			
Sensory hardness	Regression	1	1323.68	1323.68	11.82	0.0138*
	Error	6	671.69	111.95		
	Total	7	1995.37			

*Significant at P < 0.05, df: degrees of freedom.

Table 4: ANOVA Analysis of Variance results for fitted models.

	Source	DF	Adj SS	Adj MS	F-Value	P-Value
Hardness	Regression	1	9.708	9.7	12.75	0.016*
	Error	5	3.83	7.65		
	Total	6	1.36			
Fractuability	Regression	1	9.778	9.78	12.79	0.017*
	Error	5	3.88	7.15		
	Total	6	1.39			

*Significant at P < 0.05, df: degrees of freedom.

CONCLUSION

The extrudates prepared from flour blends containing sprouted horse gram and overnight soaked horse gram has more preference in terms of sensory, texture, color, expansion and nutrition than the rest of the treated samples .Extrudates prepared from flour blend containing dry untreated horse gram had overall least preference. Extrusion cooking and fermentation had some significant effect on the physical, textural and composition of the final product. The physical and functional quality of food could be improved and further enhanced with the help of extrusion. These extrudates serves as a cheap source of ready to eat snacks rich in nutrients and also low in calories .Incorporation of under-utilized locally grown legumes and millets with added functionality in the snack foods will add a new dimension for the development of new food.

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