Physico- Chemical Analysis of Sorghum based Extruded Products

P. Vijaya Deepthi
Department of APE,
CAE, ANGRAU,
Bapatla, India.

L. Edukondalu
Asst. Professor,
Department of APE, CAE, ANGRAU,
Bapatla, India.

Sivala Kumar
Professor,
Department of APE, CAE,
ANGRAU, Bapatla, India.

Lakshmi.J
Principal scientist, ANGRAU,
Gunturu, India.

***Abstract*— Sorghum (*Sorghum bicolor*) is an important staple crop in semi-arid regions of Africa and India because of its drought tolerance. This research work was focused on developing sorghum-based extruded snacks products. Processing parameters of feed including moisture contents (12%), different blends ratios of sorghum, broken rice and green gram flours (7:2:1, 6:3:1 and 5:4:1), operational parameters of the extruder like barrel temperature (110, 120 and 140^{0}C) and screw speed (150, 200 and 250 rpm) were optimized for physical and sensory properties of sorghum based extruded products. The maximum value of expansion ratio and minimum bulk density was at 110^{0}C barrel temperature at 150 rpm for 3rd blend. The sensory evaluation of the extrudates showed that samples S_3, S_6, S_9 were more acceptable.**

Keywords: Sorghum products, Extruded sorghum products, Sorghum based extruded products

INTRODUCTION

Millets are minor cereals and form the staple food for a large segment of the population in India and Africa. Millets are not only nutritionally comparable but are also superior to major cereals with respect to protein, energy, vitamins and minerals.

Sorghum (*Sorghum bicolor*) is the world's fifth leading grain in production and is a staple food for many in the arid, dry climates of Africa and Asia which contribute 65 percentage of total production. Because of its lower cost, sorghum is an attractive ingredient for the production of extruded snacks or breakfast cereals and also it's utilisation in the form of ready-to-eat snack foods is likely to increase its consumption significantly. It contains various phenolic and antioxidant compounds that could have health benefits, which make the grain suitable for developing functional foods and other applications. Sorghum bran is also a good source of dietary fibre (Rooney and Dominguez, 1991).

Rice is grown as a monocarpic annual plant in tropical areas. Rice is a cereal foodstuff which forms an important part of the diet of many people worldwide. Broken rice is a by-product of rice milling due to non-availability of technology for its conversion to value added products and developments of taste and social consideration; they are used in flour form in traditional recipes or used as animal feed. There are no major industrial processes for effective utilization of broken rice, so there is scope for the research which utilizes the broken rice.

Legumes are particularly high in protein, mineral, cholesterol-free, high in dietary fibers and low in saturated fat. India is the largest producer of mungbean (*Vigna radiata*) and is 3rd most important pulse crop of India (Choudhary *et al*., 2011) which is rich in quality proteins, minerals and vitamins.

Increasing the nutritional quality of food during food processing is always a potentially important area for research. Extrusion cooking, as a multi-step, multi-functional and thermal/mechanical process, has permitted a large number of food applications (Singh *et al*., 2007) including increasing numbers of ready-to-eat cereals, salty and sweet snacks, co-extruded snacks, indirect expanded products, croutons for soups and salads (Harper,1989;Eastman *et al*., 2001). Extrusion processing of sorghum flour has been shown to improve protein digestability and functionality which is caused due to cross-linked prolamines. Incorporation of protein and carbohydrate sources could significantly increase the protein quality and expansion ratio of sorghum-based products and provide additional functional properties. (Devi *et al.*, 2013). In view of these, the research was undertaken to develop sorghum based extruded products.

MATERIALS AND METHODOLOGY

The study was conducted at Aquacultural processing lab, Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur, India. The BTPL Lab model Twin screw extruder (EB-10 Model) with co-rotating screws was used for conducting experiments. The raw materials were procured from local markets of Vijayawada, Andhra Pradesh, India. The blend levels were selected based on the conclusions of previous studies (Pawar *et al.*, 2009).

Preparation of samples

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^{0}C) and screw speed (150, 200 and 250 rpm). All the flours were

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 10, October-2016

weighed and the moisture was adjusted by sprinkling water in the flours and mixed to prepare a homogeneous mix. After mixing the samples were stored in polyethylene bags at room temperatures for 12- 24 hrs. The samples were sieved and poured in to feed hopper and extruded using die diameter of 3 mm and product was collected at the die end.

Physico-chemical characteristics of extrudates

Expansion ratio of the extrudates

The expansion ratio (ER) for the extrudates was calculated by dividing the square of extrudate diameter (D) by the square of die diameter (d_{die}). Each value was an average of ten measurements. The diameter of the sorghum based extruded products was measured using digital callipers.

$$\text{Expansion ratio} = \frac{D^2}{d^2}$$

D= diameter of the sample

D= diameter of the die

Bulk density of the extrudates

A cylindrical section of extrudate was weighed and the diameter was measured using a vernier calliper. The bulk density of the sorghum based extruded products were then calculated as the ratio of the weight of the extrudate to the volume of extrudate.

$$\rho = \frac{w}{\pi d^2 \frac{l}{4}}$$

l= length of extrudate

d= diameter of extrudate

m= mass of the sample

Water absorption index and water solubility index of the extrudates

About 2.5 g of ground extrudates were dispersed in 25 ml of distilled water. After stirring for 30 min using magnetic stirrer dispersions were rinsed in to tared 50 ml centrifuge tube was made up to 32.5 g and then centrifuged at 3000×g for 10 min. The supernatant was decanted into a evaporating dish of known weight (Singh and Smith, 1997). The WAI was the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. The WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample.

$$WAI\left(\frac{g}{g}\right) = \frac{\text{weight of sediment}}{\text{weight of dry solids}}$$

$$WSI\,(\%) = \frac{\text{weight of dissolved solids in the supernatant}}{\text{weight of dry solids}} * 100$$

Estimation of moisture content

Moisture content of the samples was determined by using hot air oven method for every 30 days. A sample of 5gm was accurately measured into a clean and dry moisture boxes of known weight and dried in a hot air oven at 105^{0}C for 12-15 hrs, cooled in a dessicator and weighed (AOAC,1990).

$$\text{Moisture content (w.b)} = \frac{\text{initial weight} - \text{final weight}}{\text{sample weight}} * 100$$

Determination of carbohydrates (AOAC, 1990)

Reagents

- 2.5 N HCl(21.5 ml conc. HCl + 78.5 ml distilled water), Anthrone reagent : 200mg anthrone dissolved in 100 ml of ice cold 95% H_2So_4.Standard glucose: Stock- 100mg glucose dissolved in 100 ml of distilled water. Working standard: 10 ml of sock solution diluted to 100 ml with distilled water.

Procedure

A 100mg of sample was weighed and placed in boiling test tube. The sample was hydrolyzed by keeping in a boiling water bath for 3hrs with 5ml of 2.5N HCl and cooled to room temperature. After cooled to room temperature it was neutralized with solid N C until the effervecence ceases.The volume was made up to 100ml and then centrifuged. The supernatant was collected and 0.05ml and 0.1ml aliquots were taken.The standards were prepared by taking 0.2ml, 0.4ml, 0.6ml, 0.8ml, 1ml and a blank and the volume made up in all the tubes to 1ml with distilled water. Then 4ml of anthrone reagent was added and heated for 8min in a boiling water bath. The tubes were cooled under tap water and the readings were taken at wave length 630nm. A standard curve was drawn by plotting concentration of standard on X-axis and absorbance on Y-axis. From the graph the amount of carbohydrates present in the sample tube was calculated.

$$Mg\ of\ glucose = \frac{O.D\ of\ sample}{O.D\ of\ standard} * concentration\ of\ standard$$

Amount of carbohydrates present in 100g of sample

$$= \frac{Mg\ of\ glucose}{volume\ \ of\ test\ sample} * 100$$

Determination of protein content by micro Kjeldhal Method (AOAC, 1990)

Reagents

The reagents required for digestion, distillation and titration are given below respectively.

Digestion: 98% pure concentrated sulphuric acid 10ml per sample,Catalyst mixture or digestion mixture or activator (5:1) for each tube,Potassium sulphate (100gm) and copper sulphate (20gm). Distillation:40% NaOH (400gm of NaOH in 1lit of distilled water)-40ml per sample,4%Boric acid: 40gm in lit of distilled water-25ml/sample, Mixed indicator: 2parts of methyl red indicator, 1 part of Bromocresol green.Titration: 0.1N HCl or H_2 $S0_4$

Procedure:

Digestion:A sample of 0.1g to 1g was weighed and transferred in to the digestion tube.10-15ml of concentrated sulphuric acid and 5-7g of digestion activator was added to the sample.The digestion tubes were loaded into the digester and the digestion block was heated .The blank temperature

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 10, October-2016

was maintained between 320^0 C and 410^0 C. The chance of nitrogen escape is unavoidable. The sample turned colourless to light green colour at the end of digestion process. Distillation : After neutralization, acid in the digested sample was distilled with 40% NaOH on heating in SUPRA-LX, the digested samples were heated by passing steam and ammonia was liberated due to addition of 40% NaOH dissolved in 4% Boric acid. **Titration:** The solution of boric acid and mixed indicator containing the liberated ammonia was titrated against 0.1N HCl. The titration value of blank solution of boric acid and mixed indicator was determined.

Calculations :

The percentage of nitrogen present in the given sample

$$= \frac{(\text{sample titre value} - \text{blank titre}) * \text{Nofacid} * 14 * 100}{\text{sample weight} * 1000}$$

The percentage of protein present in the given sample
= % N * 6.25 factor

Sensory characteristics

Hardness:

Mechanical properties of the extrudates were determined by a crushing method using a TA – XT2 texture analyzer (Stable Micro Systems Ltd.,) equipped with a 5 kg load cell. An extrudate 54 mm long was compressed with a probe of 25mm diameter with 0.5mm/s test speed and pro test seed and 10mm/s pre test speed. The compression generates a curve with the force over distance. The highest first peak value was recorded as this value indicated the first rupture of snack at one point and this value of force was taken as a measurement for hardness (Stojceska et al., 2008).

Organoleptic evaluation:

Organoleptic evaluation of samples was carried out for consumer acceptance and preference using 7 untrained panellists selected at random from the College of Agricultural Engineering, ANGRAU, Bapatla. Taste, color and overall acceptability of the samples were rated using a 9-point hedonic.

RESULTS AND DISCUSSIONS

A total 27 samples were successfully prepared from different process parameters and different operational parameters and were optimized for physical and sensory properties.

Expansion ratio of the sorghum based extruded samples

Expansion is the most important physical property of the snack food. Starch, the main component of cereals plays major role in expansion process (Kokini et al., 1992). Increasing the level of rice flour and decreasing the level of sorghum protein will facilitate formation of starch matrix and increase water trapping, thus increasing expansion. The increase in the feed moisture and barrel temperature decreased the expansion ratio of the extrudate. Similar trend was observed in sorghum based extrudates (Mahesh *et al.*, 2012). The expansion ratio of the samples ranged from 1.82 cm to 1.3 cm represented in Fig.1 and from the graph it was observed that S_3 has the highest expansion ratio.

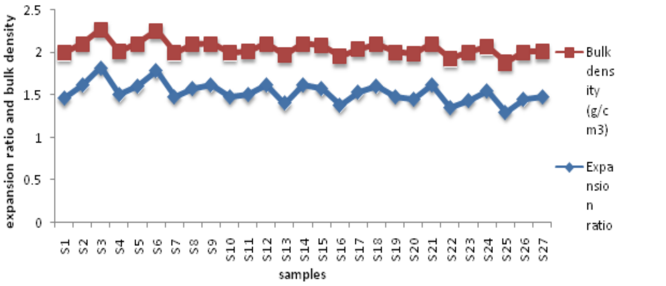

Fig 1: Effect of various parameters on expansion ratio and bulk density of the sorghum based Extruded samples

Bulk density of the sorghum based extruded products

The bulk density of the samples ranged from 0.45 g/cm^3 to 0.90 g/cm^3 represented in fig 1. The bulk density decreases with increase in barrel temperature which may be attributed due to higher starch gelatinization at higher temperature resulting in greater expansion. The bulk density increases with the increase in moisture content at higher temperatures only, which may be due to change in the molecular structure of extrudates. Similar reduction of rice extrudates density caused by increased barrel temperature has been reported by (Ilo *et al.*, 1999).

Effect of Water absorbtivity index of the sorghum based extruded products

The Water absorptivity index (WAI) measures the amount of water absorbed by starch and can be used as an index of gelatinization (Anderson *et al.*, 1969). The WAI of samples ranged from 5.18 g/g to 5.38 g/g represented in fig 2. Among all the sample S_3 showed highest WAI. Increase in WAI was directly proportional to temperature and inversely proportional to screw speed which is in agreement with the results of (Yagci and Gogus, 2008).

Effect of Water solubility index of the sorghum based extruded products

The Water solubility index (WSI) is related to the quantity of water soluble molecules, and is associated to dextrinization. In other words, WSI can be used as an indicator of the degradation of molecular compounds, and measures the starch degradation resulted from extrusion cooking (Ding *et al.*, 2005).WSI of the samples ranged from 28.4% to 29.2% represented in fig 4 Among all the samples S_9 showed highest WSI. The WSI increased as the rpm of the extruder increased and decreased with increase in barrel temperature.

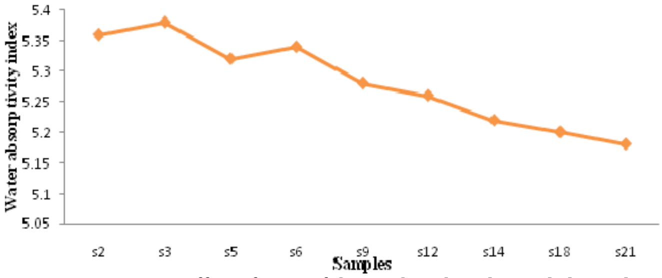

Fig 2: Effect of WAI of the sorghum based extruded samples

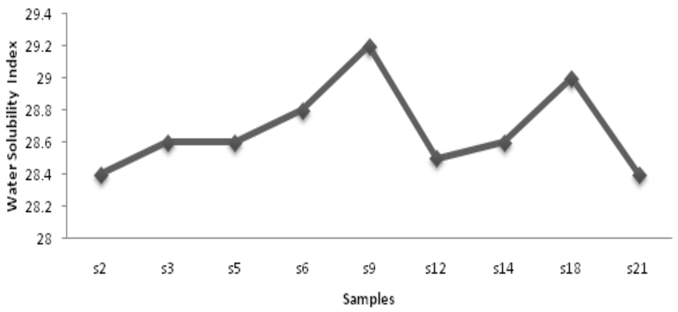

Fig 3: Effect of WSI of the sorghum based extruded samples

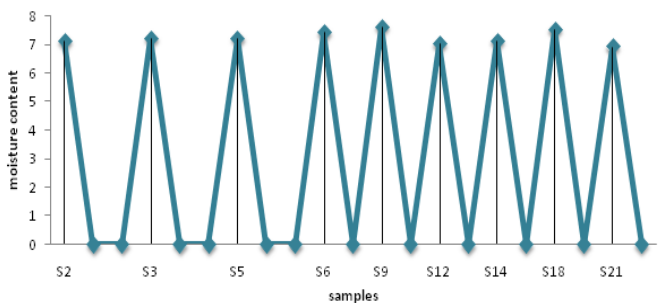

Fig 4: Effect of moisture content of sorghum based extruded samples

Effect of on moisture content of the sorghum based extruded products

The sorghum based extruded products with high expansion ratio and low bulk density Initially the products had moisture content ranging from 6.9 to 7.6% (w. b) shown in the Fig 5.

Effect of parameters on carbohydrate content of the sorghum based extruded products

The carbohydrate content of the samples ranged from 44.85 to 49.95g represented in fig 6. The sample S_6 has the highest carbohydrate content. The extrudates prepared from 3rd blend showed high carbohydrate content as there was decrease in sorghum percentage.

Effect of parameters on protein content of the sorghum based extruded products

The protein content of the samples ranged from 4.37 to1.75 g. Among the samples S_5 has the highest protein content. Proteins influences expansion through their ability to affect water distribution in the matrix and through their macromolecular structure and confirmation, which affects the extensional properties of the extruded melts (Moraru and Kokini, 2003). Similar findings were observed by (Martinez *et al*., 1990; Onwulata *et al*., 2001), who investigated the effects of whey protein concentrate and isolate on the extrusion of

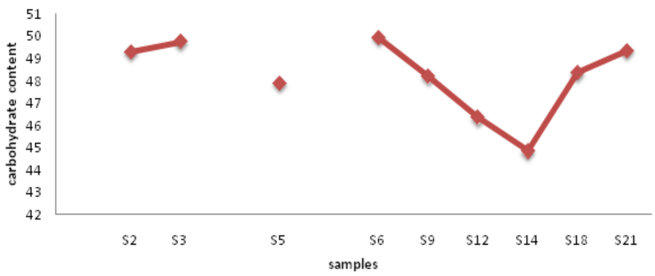

Fig 5: Effect of different parameters s on carbohydrate content of the sorghum based extruded samples

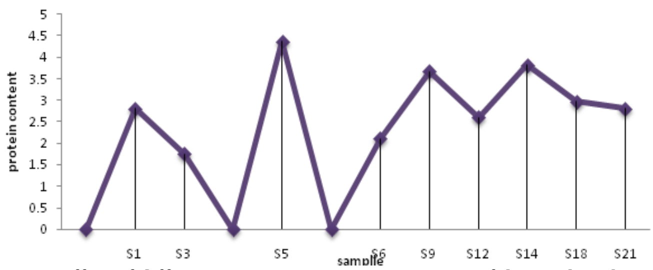

Fig 6: Effect of different parameters on protein content of the sorghum based extruded samples

Corn and rice starch and reported a reduction in expansion at higher concentrations of protein. Extrudates prepared from 3rd blend showed low protein content than the other 2 blends.

Sensory evaluation of extruded products

Hardness of the extruded products

The change in hardness of the product may be observed due to the starch gelatinization and texture of the final product. Previous studies also reported that the hardness of extrudate increased as the feed moisture content increased it might due to the reduced expansion caused by the increase in moisture content. (Badrie and Mellowes,1991). During the extrusion process, the elastic swell effect and bubble growth effect both contribute to the structure change of starch. The water acts as a plasticizer to the starch-based material reducing its viscosity and the mechanical energy dissipation in the extruder and thus the product becomes dense and bubble growth is compressed.

Sensory evaluation

The samples with higher expansion ratio and lower bulk density values were taken for sensory analysis. The sensory evaluation showed that the extrudates prepared from 5:4:1 blend ratio were more acceptable.

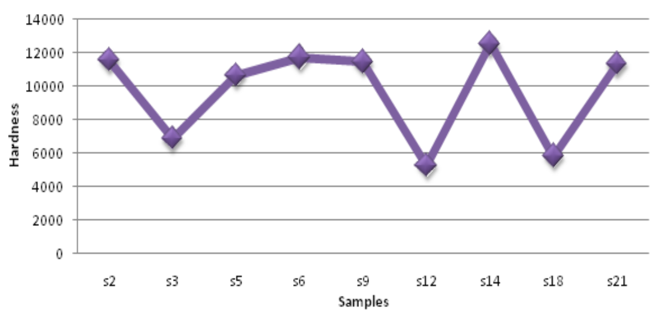

Fig 7: Effect of different treatments on texture of the sorghum based extruded products

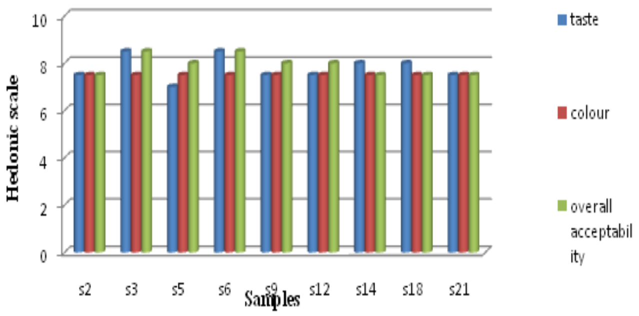

Fig 8: Organoleptic evaluation of the sorghum based extruded product samples

CONCLUSIONS

The samples prepared were evaluated for different properties. It was found that increase in temperature reduced expansion ratio. The screw speed had negligible effect. The expansion ratio was higher for sample prepared at 110^{0}C and 150 rpm. The bulk density was lower for sample with higher expansion ratio. The samples with higher expansion ratio and lower bulk density values were selected for sensory evaluation. The WSI increased as the rpm of the extruder increased and decreased with increase in barrel temperature. Increase in WAI was directly proportional to temperature and inversely proportional to screw speed. The high carbohydrate increases the expansion ration where high protein decreases expansion ratio. Ready –to-eat snack was developed using blends of sorghum, broken rice and green gram at 12% moisture content.

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