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Effect of Processing Variables on Soy-Millet Extrudate Forcomplementary Food

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Abstract

Extrusion process is novel, versatile and contemporary food processing technology. Current study was conducted on soy and sorghum blends in different ratios SS36 (36:64), SS40 (40:60), SS44 (44:56) and SS48 (48:52) to make use in complementary foods. Soy-sorghum blends were processed in pilot scale single screw extruder. Processing conditions were screw speed 487 rpm, feed rate 160 kg h^{-1} and downspout temperatureof 95^{o}C.Specific mechanical energy, moisture content and bulk density were considered as independent variables in this study. Specific mechanical energy correlated negatively with soy content in blend. Bulk density of extrudates was influenced by specific mechanical energy. Bulk density and specific mechanical energy were negatively correlated. Low bulk density was the desired characteristic to make better grain flour to be used in complementary foods.

Key words: *Bulk density, Sorghum,Soybean, Specific mechanical energy.*

Infants in many developing countries have been reported to suffer from malnutrition. This has often attributed to an inadequate intake of energy and protein and other nutrients in their diets (Dutra-de-oliveira 1991). The traditional complementary foods/weaning foods, often given to infants in certain developing countries such as India, consist of thin porridge which is made from cereal or cereal flour. Such porridges are characterized by high viscosity and low energy output per unit volume of food, necessitating frequent feedings to meet the daily energy requirements of the child. Extruded cereal and legume based complementary foods reported to be better in terms of both nutritional requirements and product quality attributed like low viscosity. Low bulk density is a requirement of the product to be used in complimentary foods.

High-quality weaning foods are still out of reach of the low-income populations in some countries because of the high costs of raw materials and lack of appropriate processing technologies (Balasubramanian *et al*., 2014). Production of weaning foods from locally available and low cost raw materials such as cereals and legumes has been recommended by the Integrated Child Development Scheme (ICDS) and FAO to overcome the malnutrition among children in such countries (Satter *et al*., 2013).Extrusion cooking is one of the contemporary food processing technologies applied for preparation of a variety of inexpensive snacks, specialty and supplementary foods (Harper and Jansen 1985). It reduces the anti-nutritional factors, renders the product microbial safe and enhances the consumer acceptability (Nibedita and Sukumar, 2003). It also reduces the destruction of nutrients, improves starch and protein digestibility. Any change in feed composition and process variables caninfluence extrusion performance as well as product quality (Desrumaux *et al.,* 1999).

Millets lack in good quality protein, so combining them with soy/pulse or milk protein would enhance both quantity and quality of protein in millet products. Such a product if developed using extrusion technology, would be low in fat, high in protein and fibre, rich in other functional aspects. The extrudates could be powdered and added with minerals to prepare suitable weaning mix for Infants. Low bulk density (BD) of extrudates is the indicator for suitability to make low viscous complementary foods (Nicole *et al*., 2010).Keeping in view the commercial potential of underutilized millet crops and highly nutritious soybean, the present study has been planned to optimize the binary blend ratio to develop protein rich low cost extruded instant flour with low bulk density.

MATERIAL AND METHODS

Preparation of composite flour

Raw material flours were mixed to make binary blends in different ratios with reference previous works (Joseph, 2016). Soy and sorghum was mixed in following ratios 36:64, 40:60, 44:56 and48:52are referring SS36, SS40, SS44 and SS48 respectively. Binary blends of soy sorghum were mixed by Hobart mixer. Binaryblend mixes of soy-sorghum were extruded on single screw pilot scale extruder X-20 (Wenger Manufacturing Inc., Sabetha, KS, USA). Extruder screw specifications: screw diameter 82.6 mm with L/D ratio of 8.1:1; screw speed 487rpm were followed. Dry feed rate was 160 kgh^{-1} for formulations made from commercially sourced flours. The preconditioned discharge temperature was always maintained above 85 °C with the help of right combination of water and steam in the preconditioner. The die had a single circular opening of 4.1 mm. Each extrusion run was performed for 20 minutes. Torque or load was obtained by digital data.

Specific Mechanical Energy

Specific mechanical energy (SME) was calculated by the method described by (Guha *et al.,* 1997), is an indicative of extrusion process severity, i.e., macromolecular transformations and interactions such as starch conversion which directly affects the final product quality (Carvalho *et al*., 2010).

$$\text{SME (kJ kg}^{-1}) = \frac{\text{Actual screw speed (rpm)}}{\text{Rated screw rate speed (rpm)}} \times \frac{\text{\% Motor torque}}{100} \times \frac{\text{Motor power rating}}{\text{Mass flow (kg/s)}}$$

The motor torque (%) during extrusion, an index for the safe operation of the machine, was obtained from the digital display of the extruder cooker. The rated motor power (37.3 kW) is the maximum power the motor corresponding to 100% torque on the screw shaft and torque at empty load was noted 34%. The highest possible rotational speed of the extruder screw is the rated rpm (636 rpm) of the screw.

Moisture content

Moist extrudate samples were collected at extruder downspout. The moisture content of the samples was determined by oven drying method based on AACC method 44-19 (2013).A sample of 2.00 ± 0.01 g was placed in an aluminium pan and heated at 135°C for 2 hours. The lids were then replaced and the pans were transferred todesiccators to cool for 30 minutes. The difference in weight of the sample pre and post oven-drying was calculated.

Bulk Density

Extrudates were collected in a fixed volume of container at extruder die exit and moist extrudates weight noted to calculate bulk density (BD). The extrudate was filled in a steel cup of known volume (V= 1L) and the top of the cup was levelled to the brim and the weight was measured on a digital weighing scale which was previously tarred to discount the weight of the steel cup. Samples were taken at initial stage of extrudates output and final stage of output to know the variations in bulk densities (Joseph, 2016).

$$\text{BD (kg m}^{-3}) = \frac{\text{Weight of extrudates}}{\text{Volume of extrudates}}$$

RESULTS AND DISCUSSION

Specific Mechanical Energy

Specific mechanical energy (SME) influences the expansion properties of extrudates. Expansion of extrudates on exiting the die was a function of SME and extensibility of the matrix (Alavi *et al*., 2011).Mass flow rate of extrudates for the binary blends were measured by collecting samples for one minute. At similar screw speeds (487 rpm) for binary blendsexhibited similar mass flow rates (0.04 kg s^{-1}). Zhu *et al*. (2010) reported that higher SME led to higher melt temperatures at the die exit and thus a greater driving force for expansion. SME values of soy-sorghum blends ranged about 176.48 to 217.40kJ kg^{-1} (Table 1).Araes (1992) reported that addition of proteins to starch rich flours above a certain level can change the behaviour of transformation into a protein type extrudates, become less expansion and more resistance to water/ moisture. Moisture acts as lubricant during extrusion thus low torque exhibited with increase soy content in binary blend (Fig.1).

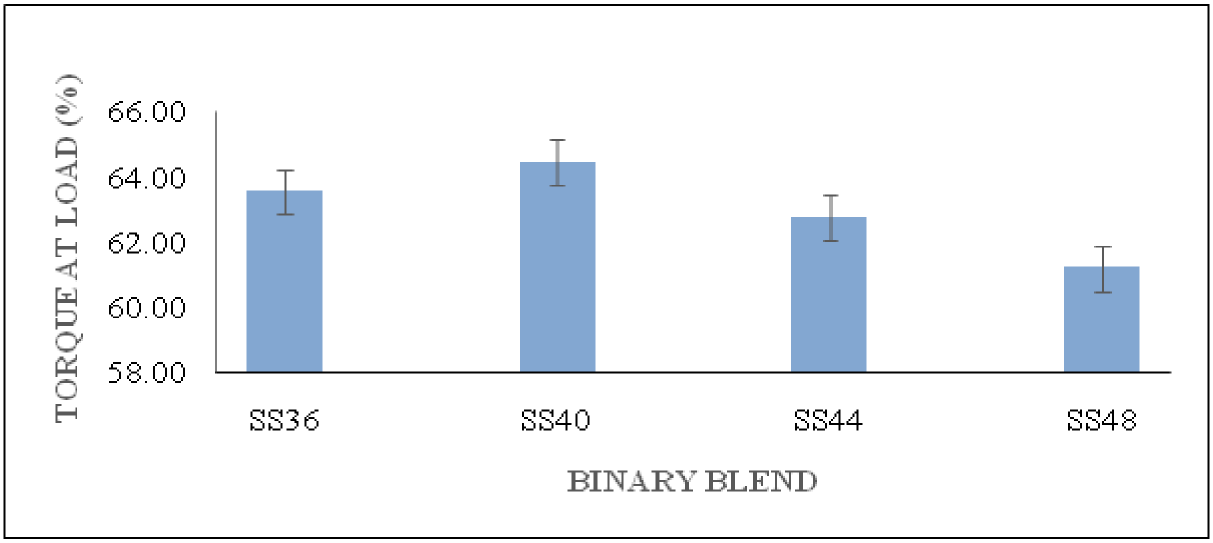

Fig.1 Motor load variations in soy sorghum binary blends

Proteins affect extrudate expansion through their ability to influence the water distribution within the extruded melt (Moraru and Kokini, 2003). Ratio of low fat soy flour in binary blend increases the protein source in blend and results decrease in SME.

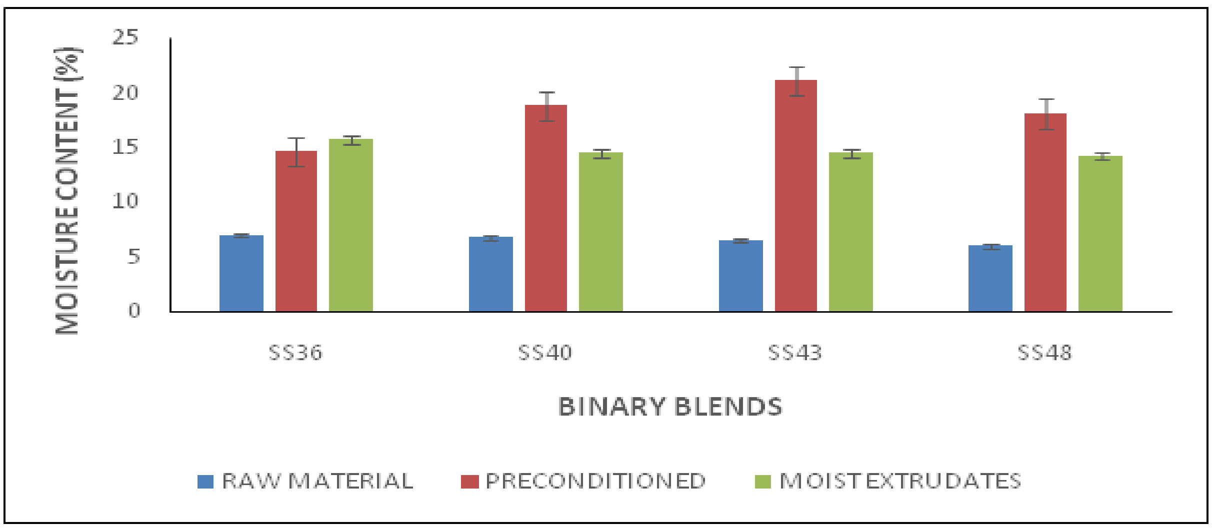

Fig. 2 Moisture contents of binary blends at stages of extrusion process

Moisture Content

Moisture content (MC) is a critical factor to understand the effect of extrusion process. It was measured at different stages namely raw blends, preconditioned and extruded blends. Samples were collected twice for each stage (after steady state of extrusion and before completing the extrusion run). Raw material moisture increased because of added water and steam in preconditioner to enable pre-gelatinization (Fig. 2). MC of extrudates decreased with increase in SMEbecause of more moisture flashed-off at die exit. It indicates degree of expansion in moist extrudates.

Bulk Density

Bulk density (BD) is an important physical property of the extruded products, determines the degree of extrudate puffing as it exits the extruder; it considers expansion in all directions (Altan *et al.*, 2008). Low moisture content of the starch may restrict the material flow inside the extruder barrel, which would perhaps increase the degree of starch gelatinisation, and thus, expansion. BD of binary blends ranged from 150.88 to 210.13 kg m^{-3} highest being for binary blend ratioSS48 and least being for SS36 (Table 2). Moisture content of extrudates decreased with increase in BD. At similar processing conditions, increase in soy content (more protein) in binary blend

Table 1. Screw speed and SME for soy

SI. No.	Binary blend	SME (kJ kg^{-1})
1	SS36	210.83 ± 29.13
2	SS40	217.40 ± 21.42
3	SS44	205.26 ± 24.21
4	SS48	176.48 ± 20.64

Table 2. Bulk density of extruded binary blends

SI. No.	Binary blend	Bulk density (kg m^{-3})
1	SS36	150.88±13.26
2	SS40	166.38±19.27
3	SS44	193.25±3.18
4	SS48	210.13±15.73

All measured values are Mean ± standard deviation

led to poor moisture distribution and thus led to variations in motor load. As motor load decreases corresponding SME drops and thus insufficient pressure built at extruder die results poor expansion (Zhu *et al*., 2010).SME and BD were negatively correlated and similar observations were quoted by Joseph (2016) and Seth and Rajamanickam (2012).

Conclusion

Binary blend ratios of soy sorghum influenced the extrusion process severity. Increase in soy content in blend ratiodecreased SME. Low SME led to high BD of the extrudate. Proteininteractions influenced the moisture distribution in extrudates and thus BD varied. SS36 and SS40 blends which have relatively less BD are suitable to prepare instant complementary food.

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