Evaluation of Maize/Soybean Blends for Snack Production by Extrusion Cooking

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ABSTRACT

The effect of component raw material ratio and extrusion temperature on physico-chemical and mechanical characteristics as well as acceptability of some snack products was investigated. Five different blends of maize and soybeans were extruded at five different temperatures in a total of nine runs, using a computer aided experimental design. Maize was found to enhance colour and expansion while soybeans enhanced textural characteristics of the extrudates. Extrudates of blends had better physico-chemical and textural properties than those of maize or soybean alone. Temperature also enhanced textural and mechanical properties. The sample with optimum characteristics and most acceptable is a 75/25 maize/soybean blend extruded at 150 °C, followed by the 82/18 blend at 168 °C.

Keywords: Cereal grains, Extrudates, Physico-chemical properties, Textural characteristics.

I. INTRODUCTION

Cereal grains are an important source of food, energy, and valuable dietary nutrients. Notable ones grown in Nigeria are Maize, Sorghum, Rice, Millet, Acha and more recently Wheat. Nigeria is the largest producer of cereals in the whole of Africa, with a production figure of about 26.2 million tonnes [1] Unlike the readily perishable fruits and vegetables, these grains are consumed to a considerably larger extent because they are versatile, durable and of longer shelf life [2], [3] though postharvest losses of about 20% are still recorded [1].

Cereals contribute about 75% of calories and 67% of protein consumed all over the world and about 42% of the total daily calories and 49% of the total daily protein, of all the food crops available to Nigerians [4], [5] Despite the prominent role of these cereals however, their processing and utilization has not been maximally explored in Nigeria to increase and improve the products obtained from them. Traditionally, they are simply boiled and eaten or processed by wet milling to make porridges of low nutritional value or dry milled into meals that are made into stiff puddings, taken with soup. They are sometimes roasted or fried and more recently baked as snacks [6].

This work was therefore undertaken to develop some acceptable and nutritious snack products from blends of maize and soybeans by extrusion cooking. Maize was chosen for this study because it is cheaper [7], more abundant and of higher yield [8], [9] while soybeans was included to complement the maize and improve the nutritional quality of the resulting product. Processing by extrusion cooking was chosen because it offers a means of diversification in the utilization of cereals and permits the combination of different raw materials into novel products of better nutritional quality. Ultimately, postharvest wastage and loss will be reduced and food security enhanced.

II. MATERIALS AND METHODS

A. Raw Material Procurement and Preparation

Major raw materials used were maize grains (Zea mays, yellow variety) and Soybeans (Glycine max, yellow variety). Defatted soyflour was obtained from Energy Foods Company, Mysore while maize was purchased from a local market in Mysore and was processed into flour by cleaning, dehulling, germ removal, milling and sieving. Particle size of the flours was kept at 250 μ to ensure proper blending of the components.

B. Extrusion Procedure and Conditions

The extrusion process was done at the Defence Food Research Laboratory, Mysore. A single screw, high shear Brabender extrusion cooker (Model DCE 330) was used and a computerized design of experiment, with five different maize/soybean feed ratios extruded at five different temperatures in a total of nine experimental runs. The experimental design and runs are presented in Table I.

Soybean level was kept at a minimum of 15%, to achieve a limiting amino acid level of not less than 50% [10] and a maximum of 35%, to keep possible undesirable effect on product taste and odour to a minimum. Feed rate was fixed at 175 g/min and a moisture content of 22%. Extruder screw speed was 100 rpm with a die diameter of 5mm and pressure of 20 dynes. A temperature range of 125-175 °C was chosen to ensure adequate cooking of the product.

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C. Product Analyses and Evaluations

These were carried out at the Central Food Technology Research Institute, also in Mysore.

1) Physico-chemical Measurements

Volume, expansion index, density and texture of the extrudates were determined.

Volume (in cm$^3$) was calculated using the formula $\pi r^2 L$ where $r$ is radius and $L$ is length, because the extrudates are cylindrical in shape.

Length and diameter were measured in mm using a micrometer screw gauge. Density (in g/cm$^3$) was calculated as weight of extrudate in relation to volume.

Expansion index (EI) was determined as the cross sectional area of extrudate in relation to the cross sectional area of extruder outlet die and is dimensionless.

Texture was measured as hardness using a Kyo hardness tester and expressed in g. Water absorption index (WAI) was measured in g/g by the method of [11].

2) Consumer acceptance of the extrudates

Consumer acceptance of the extrudates was carried out by sensory evaluation, using a semi trained panel of 25 members and a 7-point hedonic scale ranging from dislike very much (= 1) to like very much (= 6) [12]. Attributes rated were colour, texture, flavour and overall acceptability. Analysis of variance was done to determine differences among the samples and to select the most acceptable or preferred sample.

3) Proximate composition

Proximate composition of the flours and extrudates was determined according to the standard procedures of [13].

III. RESULTS AND DISCUSSION

The study design and results obtained are presented in Tables I-IV.

A. Experimental Design

The design employed and experimental runs used in this study are as shown in Table I.

| Experimental run | Maize/Soybean ratio | Temperature (°C) |
|------------------|---------------------|-----------------|
| 1                | 85/15               | 150             |
| 2                | 82/18               | 132             |
| 3                | 82/18               | 168             |
| 4                | 75/25               | 125             |
| 5                | 75/25               | 150             |
| 6                | 75/25               | 175             |
| 7                | 68/32               | 132             |
| 8                | 68/32               | 168             |
| 9                | 65/35               | 150             |

B. Physico-chemical Properties of Extrudates

Physico-chemical properties of the extrudates from flours of maize, soybean and their blends are shown in Table II.

From the physico-chemical results presented in Table II, it can be observed that extrudates from maize flour alone at both 125 °C and 150 °C had maximum volumes of 1.81 cm$^3$ and 1.82 cm$^3$ and expansion indices of 4.61 and 4.63 respectively, indicating a light and porous product. This is basically as a result of the starchy nature of maize and the ability of starch to expand [14, 15]. Expansion depends mainly on starch gelatinization [16] and this in turn is influenced by the moisture content, mechanical shear and temperature of the feed material during extrusion [15, 17].

| Sample | Volume (cm$^3$) | Density (g/cm$^3$) | EI* | Hardness (g) | WAI* |
|--------|-----------------|-------------------|-----|------------|------|
| MF*, 125°C | 1.81 | 0.44 | 4.61 | 11.10 | 5.47 |
| MF, 150°C   | 1.82 | 0.39 | 4.63 | 8.05  | 5.67 |
| SF*, 125°C  | 0.49 | 1.09 | 1.25 | 3.16  | 4.10 |
| SF, 150°C   | 0.52 | 1.07 | 1.32 | 3.02  | 4.48 |
| 85:15*, 150°C | 1.41 | 0.40 | 3.59 | 6.35  | 5.06 |
| 82:18, 132°C | 1.40 | 0.46 | 3.56 | 2.60  | 4.50 |
| 82:18, 168°C | 1.28 | 0.44 | 3.26 | 2.18  | 4.97 |
| 75:25, 125°C | 1.26 | 0.48 | 3.22 | 6.22  | 4.03 |
| 75:25, 150°C | 1.30 | 0.45 | 3.51 | 2.48  | 4.72 |
| 75:25, 175°C | 1.23 | 0.39 | 3.14 | 7.77  | 5.05 |
| 68:32, 132°C | 1.31 | 0.42 | 3.24 | 5.85  | 4.10 |
| 68:32, 168°C | 1.24 | 0.46 | 3.17 | 2.02  | 4.23 |
| 65:35, 150°C | 1.21 | 0.47 | 3.09 | 2.54  | 4.44 |

* EI = Expansion index, WAI = Water absorption index, MF = Maize flour, SF = Soybean flour, ^* = MF/SF ratio.

The extrudates from soybean flour alone had the lowest expansion indices of 1.25 and 1.32 at 125 °C and 150 °C respectively and were more dense than the other extrudates due to the proteinous nature of soybeans and also as a result of the very low presence (less than 1%) of starch [18, 19]. From this, the importance of starch and the role played by the maize and soybean in the blends can be clearly seen. The more the maize (and starch) content of the extrudate, the more is the expansion while the more the soybean (protein), the less is the expansion [14, 20].

Hardness showed a wide variation among the extrudate samples. The gelatinized starch in maize, on cooling set into a hard plastic mass which made the extrudates from maize alone the hardest of the samples, with values of 11.13 g and 8.05 g at 125 °C and 150 °C, respectively (Table II). The extrudates from soybean alone were comparatively brittle and less hard. The protein molecules in the soybean formed fibres that were aligned in such a way that made breaking easy.

Water absorption Index (WAI), which is a measure of starch gelatinization, increased with increasing content of maize in the blend as maize is the source of starch. WAI was also observed to increase with increasing temperature because of starch degradation and the release of amylose and amylopectin which increase with temperature up to a certain level [21]. The higher the maize content in the blend and the temperature of extrusion, the more gelatinized is the resulting product [22].

C. Sensory Evaluation

Results of sensory evaluation to determine acceptability of the extrudates are presented in Table III.

| Sample | C* | T* | F* | O/A* | Total |
|--------|----|----|----|------|-------|
| 85:15*, 150°C | 5.1 | 4.3 | 3.6 | 3.9 | 16.9 |
| 82:18, 132°C | 4.6 | 3.4 | 3.6 | 4.0 | 15.6 |
| 82:18, 168°C | 3.6 | 4.6 | 4.5b | 4.5 | 17.2 |
| 75:25, 125°C | 4.1 | 2.6 | 2.7 | 2.5 | 11.9 |
| 75:25, 150°C | 4.3 | 4.5 | 4.6 | 4.8 | 18.2 |
| 75:25, 175°C | 2.5 | 4.2 | 4.3 | 4.3 | 15.3 |
| 68:32, 132°C | 3.7 | 3.4 | 3.8 | 3.0 | 13.6 |
| 68:32, 168°C | 2.6 | 3.6 | 3.8 | 3.7 | 13.7 |
| 65:35, 150°C | 3.5 | 3.8 | 3.6 | 3.8 | 14.7 |

Means with same superscript within a column are not significantly different (p > 0.05), ^ = MF/SF ratio, C= Colour, T= Texture, F= Flavour, O/A= Overall acceptability.

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The effect of maize/soybean ratio on the organoleptic properties of the extrudates can be observed from the results of sensory evaluation presented in Table III. The 85:15 maize/soybean blend extruded at 150 °C had the highest score for colour at 5.1 and this can be attributed to the attractive yellow colour of the maize, as this sample had the maximum maize content. The 82:18, 168 °C sample had the highest score for texture (crispness) at 4.6, though not significantly different from the 75:25, 150 °C (with a score of 4.5), which was the next best sample in texture. Flavour, overall acceptability and total scores were highest in the 75:25, 150 °C sample at 4.6, 4.8 and 18.2, respectively, making this sample to clearly stand out as the most acceptable of all the extrudates.

Feed components and level of incorporation seem to be a very crucial determinant of acceptability. The samples with more soybeans (> 25%) had lower scores than samples with less. This can be attributed to the characteristic beany taste and odour of soybeans. Addition of spices and flavouring materials can be used to resolve this issue and make the products more acceptable.

Temperature also seems to enhance the texture and flavour characteristics of the extrudates as the same feed material extruded at a lower temperature had lower scores. Similarly, in all the blends except the 75:25, 175 °C, samples extruded at higher temperatures had higher texture and flavour scores. With the 75:25, 175 °C sample, expansion was actually more during extrusion than at 150 °C and 125 °C but the product structure was rather weak and collapsed slightly on cooling, resulting in a rough appearance. This phenomenon was also reported by [21] that when extrusion temperature exceeds a certain level, starch molecules may undergo degradation and give reduced expansion.

D. Proximate Composition of Flours and Extrudates

Proximate composition of the maize flour, soybean flour and blends used for extrusion as well as some selected extrudates are presented in Table IV.

From the results, it can be observed that the feed materials are quite similar in composition but widely different from the maize and soybean flours from which they were composed. The addition of soybean to maize, even at the lowest level of 15% used, improved the protein and ash contents of the blends resulting in a more superior material than maize alone.

In the extrudates, moisture content was observed to be stable around 6% while fat was reduced, compared with the values before extrusion, likely due to the formation of amylose-lipid complexes, leading to lower extractability of fat [23] Ash was increased, possibly due to addition of iron and other metals from parts of the extruder [22], [24]. Protein also increased, particularly in the 75:25, 150 °C sample. This was confirmed qualitatively by soaking cut sections of the samples in a protein stain (Coomasie Blue R-250) and the 75:25, 150 °C clearly stained more than the others. It was also observed that the protein molecules formed aggregates which were localised around the centre area, possibly because they move slower during extrusion while the starch molecules which move faster are on the outer portion and expand to give a porous product structure. This phenomenon indicates the different and independent behaviour of the maize and soybean during extrusion.

IV. CONCLUSION AND RECOMMENDATIONS

This study has shown that acceptable, ready to eat snack products can be developed by extrusion cooking of maize and soybean blends. Soybean improved the nutritional quality and physicochemical characteristics of the products and the blends gave extrudates of better properties compared with those from maize or soybean alone. Maize enhanced expansion and gave desirable colour to the product while soybeans enhanced texture characteristics.

Temperature was also found to have a beneficial effect on product texture and flavour. From the same blend, sample extruded at higher temperature was preferred.

Among the different blends investigated, the most acceptable was the 75:25, 150 °C sample, followed by the 82:18, 168 °C. The use of spices and flavouring materials is recommended to further improve product acceptability as well as presentation in various shapes, sizes and designs to give product variety.

On the whole, the development of snack foods by extrusion cooking is promising and various formulations can be made to give a wide range of products for different applications.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.
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