# Development of Quality Protein Maize based breakfast cereal

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## ABSTRACT

The study was carried out at ICAR-IARI, New Delhi during 2012–16 to evaluate the effect of extrusion parameters namely, barrel temperature (100–140°C), screw speed (300-500 rpm) and feed moisture addition (6–18% wb) on quality of QPM (Var. HQPM1) based expanded extruded product. The optimum extrusion processing condition (9.75% feed moisture addition, 125°C temperature and 461 rpm screw speed) was established for QPM. At this extrusion condition, the effect of addition of finger millet and carrot powder on quality of QPM based extruded product was determined. Addition of up to 20% finger millet was found optimum for retaining acceptable colour in the extrudate. Addition of carrot powder to QPM-finger millet base imparted reddish colour to the extruded product and also led to decrease in expansion ratio and increase in bulk density. Colour ("a-value") increased with increase in carrot powder in the sample, indicating increase in redness of the product. Based on physical appearance of the sample, as well as expansion ratio and a-value, addition of 10% carrot powder was considered optimum. A breakfast cereal was thus developed through extrusion processing at optimum conditions using ingredients composition of 72% maize (QPM and normal maize), 18% finger millet and 10% carrot powder. The final product obtained had 9.6% protein, 1.5% fat, 3.4% fibre, 2 mg/100g β-carotene, 3 mg/100g iron and 122 mg/100g calcium. Amino acids (especially tryptophan and lysine) were higher in quality protein maize based product than normal maize based product.

The volume of breakfast cereal segment consumed in India was about 351.8 Mkg in 2018, which is expected to rise to 374.4 Mkg in 2023 (Statistica, 2019). Extrusion processing is being used to produce a number of breakfast cereals. Food extrusion, a high temperature short time cooking process has been reported for developing numerous food products and their advantages (Jha and Prasad 1997, Jha and Prasad 2003, Chikkanna *et al.* 2015, Tiwari and Jha 2016, Jalgaonkar and Jha 2016, Kaukab *et al.* 2017, Krishnakumar *et al.* 2017, Tiwari and Jha 2017a, Tiwari and Jha 2017b, Faisal *et al.* 2017, Arunkumar *et al.* 2018, Faisal *et al.* 2018, Jalgaonkar *et al.* 2018a, Jalgaonkar *et al.* 2018b, Jalgaonkar *et al.* 2018c, Jalgaonkar *et al.* 2019). It is considered as the most efficient food processing technique which is continuous and also ensures uniform quality product. Corn, commonly known as Maize, is third most grown staple crop in India. Quality Protein Maize (QPM) falls under specialty corns and has catered use in food processing industry. It has been reported that QPM contains nearly twice more usable protein than other maize (Hossain

*et al.* 2018). Genetic improvement in HQPM series hybrids led to increase the provitamin A content from 2.14-2.48 µg/g to 10.58 µg/g (Zunjare *et al.* 2018).

Finger millet also known as ragi is popular millet in India. It has a unique property of slow digestion. It contains adequate amount of thiamine, iron and calcium with a rich source of dietary fibres (Gopalan *et al.* 2004). Carrots, the most important source of dietary carotenoids contain the highest amount of β-carotene of the common fruits and vegetables (Desobry *et al.* 1998). β-carotene constitutes 60–80% of the carotenoids in carrots, followed by α-carotene (10-40%), lutein (1–5%), and other minor carotenoids (0.1–1.0%) (Chen *et al.* 1995). The objective of the study was to determine the effect of extrusion process variables on quality of breakfast cereal based on QPM. The effects of addition of finger millet in QPM and carrot powder in QPM-finger millet on quality of extrudates were determined.

## MATERIALS AND METHODS

Maize, finger millet and carrot were used as ingredients for product development. Maize (HQPM1 and normal maize) and carrot were obtained from the farm of Indian Agricultural Research Institute, New Delhi during 2012-16. Finger millet (GPU 28) was obtained from GKVK, Bangalore. The raw ingredients obtained from the farm were cleaned thoroughly. Maize and finger millet was ground using laboratory hammer mill (Sanco, Delhi). Carrot was pulped and dried

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in a tray drier at 60°C. The dried carrot was ground in a mixer-grinder. Extrusion experiments were performed on a co-rotating and intermeshing twin-screw extruder (BTPL, Kolkata, India) having length to diameter ratio (*L/D*) as 8:1. For making round shape product, cutter speed was first determined through trial runs. For extrusion, the moisture content of the flour blend was adjusted at varying levels by addition of required amount of water and thorough mixing. Raw materials were fed at constant rate into the extruder with a twin-screw volumetric feeder. A variable speed die face cutter with two blades was used to cut the extrudates. Samples were collected for 5 min in open pans and allowed to come to room temperature and then dried in tray dryer to final product moisture (4% d.b.) for storage.

Extrusion experiment was first laid down with three independent factors at five levels using completely randomized factorial design to investigate the effects of extrusion conditions on the product responses of the maize alone. The independent variables were feed moisture content (6–18%, w.b.), screw speed (300–500 rpm), and barrel temperature of the exit end (100–140°C). The range of variables was selected based on trial runs on the machine. Data was analyzed using PROC GLM of SAS (SAS, 2008).

*Determination of effect of finger millet and carrot powder in QPM on extruded product quality*: Based on nutritional profile of products available in the market in similar category, the finger millet, and carrot powder were selected as additive in QPM. The effects of addition of finger millet, and carrot powder in corn were determined. Finger millet was added in QPM at 5, 10, 15, 20, 25 and 30% levels. Subsequently, carrot at 2, 4, 6, 8, 10 and 12% were added in QPM-finger millet and extrudate was evaluated for quality like expansion ratio and colour.

*Determination of properties of extrudates*

*Moisture content:* Moisture content of a flour sample was determined by drying at 105±2°C for 24 h in an oven to constant mass (AOAC 2000).

*Expansion ratio (ER)*: ER was determined using the methods followed by Jha and Prasad (1997), Chikanna *et al.* (2015), Tiwari and Jha (2016), Krishnakumar *et al.* (2017). It was calculated as the ratio of size of extrudate and size of die used. Extrudate diameter was measured using a digital vernier calliper having accuracy ±0.01mm.

*Colour*: Colour of the extrudate was measured using Hunter colour lab (Model No. LX 16244, Hunter associates laboratory, Virginia) in terms of CIE L*, a* and b* values as per method reported by Kumar *et al.* (2012). Lightness and darkness, redness and greenness and yellowness and blueness were measured with the positive and negative values of L*, a* and b*, respectively. The sensor was first standardised with white and black tiles to measure the colour.

*Textural measurement*: The texture of extrudate was measured following the method suggested by Jha *et al.* (2010), Tiwari and Jha (2016) using the Texture analyzer (Model: *TA+HDi,* Stable Micro Systems, UK) attached with 50 kg load cell. A 2 mm cylinder probe was used to determine hardness. The test was carried out using test speed of 0.5 mm/s and compression distance of 90% of the product size. A force–time curve was obtained. The maximum force was taken as the hardness of the extrudate.

*Total and β-carotene*: Total carotenoids content was determined by a method described by Ranganna (1986). β- carotene was determined through open column chromatography following the method reported by Ha *et al.* (2010).

*Amino acid profiling*: Amino acids composition was determined by UHPLC (Dionex- Thermofisher, USA) using C-18 column 2.2μ, 100 mm column (Thermofisher, USA).

## RESULTS AND DISCUSSION

*Effect of extrusion process parameters on expansion property of QPM extrudate*: The extrusion of quality protein maize flour was carried out to prepare round shape extrudate. The properties of the extrudate as influenced by the extrusion variables were quantified and related using multiple regression.

*Expansion ratio*: Expansion ratio (ER) of QPM extrudate varied from 1.94–3.12. The ER increased with increase in temperature up to about 125°C and decreased thereafter. ER increased with increase in screw speed. With increase in moisture addition up to about 9%, ER increased, but decreased thereafter. Increase in ER could be attributed to increase in gelatinization of starch whereas subsequent decrease could be due to degradation of starch molecule. Similar effects of barrel temperature, screw speed and moisture content were also reported by Faisal *et al.* (2017) for corn based extrudates, Ajita and Jha (2016) for pearl millet based extrudate and Krishnakumar *et al.* (2017) for barnyard based extrudate.

A relationship (Eq. 1) for prediction of ER of corn extrudate was obtained by fitting second order polynomial with experimental data using multiple regression. Coefficient of determination ($R^2$) of 0.6389 indicated that 63.89% variability in expansion ratio could be explained by the eq. 1.

$$ER = -2.12+0.066t-0.0002t^2-0.00002s*t+0.0007m*t -0.005m^2$$
$$(R^2=0.638) \tag{1}$$

Where, t=temperature (°C); s=screw speed and m=Moisture addition (%).

Stationary point was determined as 125°C, 461 rpm and 9.75% moisture addition. The predicted ER at stationary point was 2.88. Subsequently canonical analysis was done to find the nature of stationary point. The eigen (λ) values obtained at the stationary point were -0.0000011, -0.00022 and -0.00503 i.e. all negative values, indicating the stationary point to be maximum. Thus maximum expansion, a desirable trait for such product could be obtained at 125°C, 461 rpm and 9.75% moisture addition. Hence, at these extrusion conditions the subsequent study was conducted.

*Effect of addition of finger millet and carrot powder in QPM on extruded product quality*

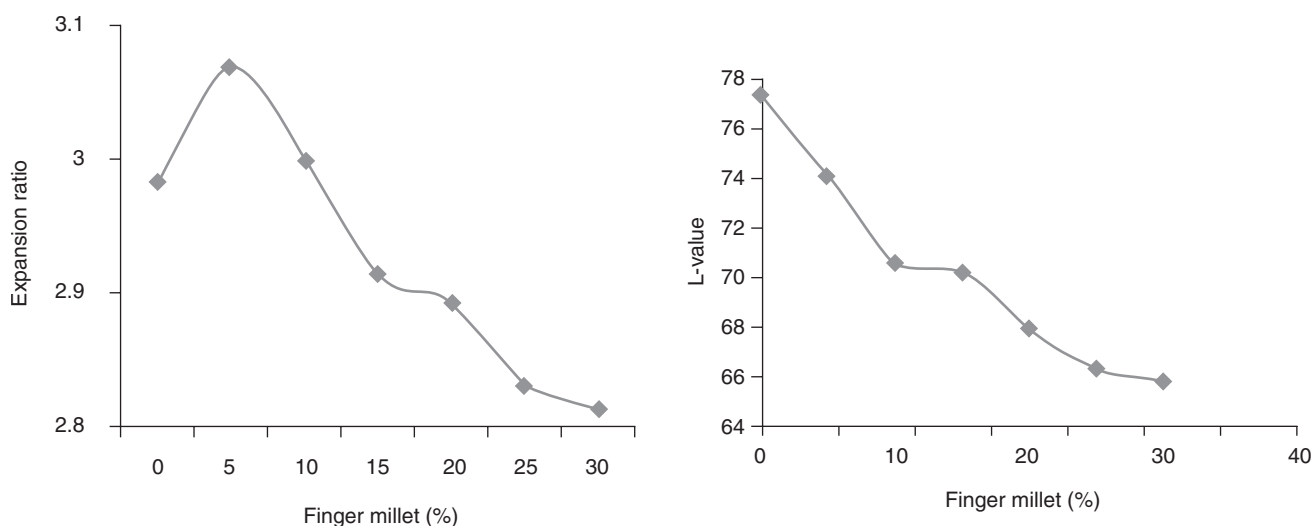Effect of addition of finger millet: The ER of extrudate

Fig 1  Effect of finger millet addition on properties of corn extrudate.

increased up to 5% addition of finger millet, beyond which it was found to be decreasing on further addition of finger millet (Fig 1). It could not be clearly ascertained as to why the addition of 5% finger millet led to increase in expansion. It was also observed that up to 30% addition of finger millet, the ER could be obtained in the acceptable range for breakfast cereal. But, colour of the extrudate started darkening on addition of 25% and more finger millet. As evident from Fig 2, L value decreased with addition of finger millet. However, physically dark colour of the extrudate dominated on addition of 25% or more finger millet. Hence, addition of 20% finger millet was considered optimum.

Effect of addition of carrot powder on corn-finger millet based extrudate: Carrot powder was added in the corn-finger millet mixture at varying levels. Expansion ratio was almost not affected up to 6% carrot powder addition but with further addition, it decreased rapidly (Fig 2).

Addition of carrot powder imparted colour to the extruded product. It was observed that "a-value" increased (Fig 2) with increase in carrot powder in the sample,

indicating increase in redness of the product. Similar result has been reported by Kumar *et al.* (2012) and Jalgaonkar *et al.* (2018) on addition of carrot powder in extruded product based on rice and pearl millet, respectively. Based on physical appearance of the sample, as well as expansion ratio and a-value, addition of 10% carrot powder was considered optimum. Thus ingredient composition of 72% maize, 18% finger millet and 10% carrot powder was finally selected for making breakfast cereal.

*Nutritional properties of developed QPM based breakfast cereal*: Nutritional composition (Table 1) of the breakfast cereal product revealed that it was rich in protein (9.6%). Additionally, the product had 2 mg/100 g β-carotene. The amino acids profiles in the products were determined (Table 2) for both QPM and normal maize based breakfast cereal. As expected, amino acids were higher in QPM based product compared to field maize based product. Two essential amino acids ie tryptophan and lysine were 53.7% and 45% higher in QPM based product than normal maize.
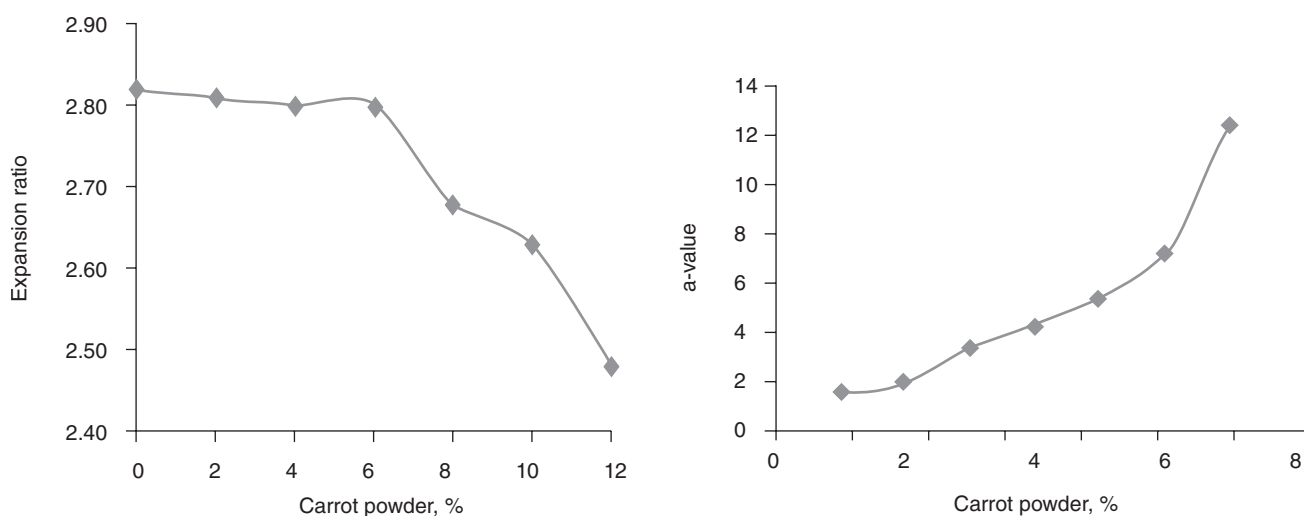
Extrusion processing at 125°C, 461 rpm and 9.75%



Fig 2  Effect of carrot powder addition on properties of extrudate.

Table 1   Nutritional composition of the breakfast cereal product

| Particular | Quantity |
|---|---|
| Energy, kCal/100g | 382 |
| Total carbohydrate, % | 82.5 |
| Available carbohydrate, % | 79.1 |
| Protein, % | 9.6 |
| Fibre, % | 3.4 |
| Ash, % | 2.4 |
| Fat, % | 1.5 |
| Moisture, % | 4.0 |
| Total carotene, mg/100g | 2.9 |
| $\beta$-carotene, mg/100g | 2.0 |
| Fe, mg/100g | 3.0 |
| Calcium, mg/100g | 122 |

Table 2   Amino acids composition of the extruded breakfast cereal product

| Amino acid | Normal corn based product (nmole/g) | QPM based product (nmole/g) | Difference |
|---|---|---|---|
| Asparagine | 12.17 | 13.67 | 12.32% |
| Glutamine | 26.81 | 28.94 | 7.94% |
| Serine | 8.16 | 8.29 | 1.59% |
| Glycine | 10.97 | 14.91 | 35.91% |
| Cysteine | 2.54 | 3.49 | 37.40% |
| Arginine | 16.20 | 15.56 | -3.95% |
| Alanine | 4.18 | 4.29 | 2.63% |
| Tyrosine | 3.68 | 4.37 | 18.75% |
| Proline | 5.61 | 9.56 | 70.40% |
| Valine | 8.66 | 10.92 | 26.09% |
| Tryptophan | 80.97 | 124.46 | 53.71% |
| Phenylalanine | 5.64 | 5.58 | -1.06% |
| Leucine | 17.07 | 15.22 | -10.83% |
| Lysine | 3.31 | 4.80 | 45.01% |
| Threonine | 5.62 | 6.75 | 20.10% |

moisture addition was established as most suitable for maximum expansion of QPM alone as ingredient. Addition of finger millet in QPM led to decrease in expansion ratio and colour (L value) beyond 5%. Addition of up to 20% finger millet was found optimum for retaining desirable colour in the extrudate. Addition of carrot powder to QPM-finger millet base imparted colour to the extruded product and led to decrease in expansion ratio. Colour (a-value) increased with increase in carrot powder in the sample, indicating increase in redness of the product. Based on physical appearance of the sample, as well as expansion ratio and a-value, addition of 10% carrot powder was considered optimum. Thus overall ingredients composition of 72% maize, 18% finger millet and 10% carrot powder was determined as most suitable combination for acceptable quality extrudate (breakfast cereal). Amino acids were higher in quality protein maize based product than normal maize based product.

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