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RESEARCH PAPER

Quality protein maize for food and feed purpose: A nutritive approach

Navjot Kaur[1] · Ramesh Kumar[1] · Baljit Singh[2] · D. P. Chaudhary[1]

Abstract: Protein energy under nutrition (PEU) and micronutrient deficiency is common in countries where population mainly depends upon cereal grains including maize to derive most of their nutritional requirements. So, proper nutrition through different ways such as nutrient supplementation and biofortification is essential for improvement and maintenance of human health. In spite of important uses of maize, it is deficient in two essential amino acid i.e. lysine and tryptophan along with moderate deficiency of isoleucine. These deficiencies have been addressed through the development of nutritionally improved maize known as Quality Protein Maize (QPM) which possesses the desired concentration of lysine and tryptophan as recommended by Food and Agricultural Organization. Development of QPM holds a great promise to signify its importance not only as quality food but also as quality feed for poultry, piggery and animal sectors.

Keywords: Food · Feed · Normal maize · Quality protein maize

Introduction

Maize (*Zea mays* L.) is gaining popularity among all the cereal grains, due to its increased utilization as food (23 per cent) and livestock feed (63 per cent). It is known as 'Queen of Cereals' and ranks third in production after wheat and rice. Most of the population residing in the developing countries including Africa and Latin America derive almost half of their protein and energy requirements from maize. Maize is consumed in different forms such as corn flakes, cornmeal, porridge, chapattis, flat breads, flour, tortillas, and breakfast cereals etc. India produces various specialty maize such as Quality Protein Maize, pop corn, sweet corn and baby corn along with high yielding maize genotypes (flint and dent corn). Although it contains about 10 per cent of protein, but the nutritional quality of maize protein is poor due to its higher prolamine fraction and lower tryptophan, lysine and threonine content than required for proper nutrition (Carrillo *et al.,* 2007). The low protein quality in the diet increases the risk of Protein Energy Under-nutrition (PEU) which adversely affects pregnant women and children. PEU results in development of kwashiorkor or pellagra also termed as "weaning disease". Pellagra emerges from the chronic protein imbalance which increases susceptibility to diseases like gastroenteritis and tuberculosis. So, it becomes important to supplement food with an alternative protein source rich in lysine and tryptophan (Liu, 2007; Ullah *et al.,* 2010).

Lysine and tryptophan play an important role in the growth of tissues and protein synthesis. In the body, tryptophan converts to niacin and reduces the chances of pellagra. Biofortification, bacterial fermentation and nutrient supplementation are major strategies to lessen the risk of protein energy under nutrition. The requirement to ameliorate the nutritional profile of maize has been recognized by using conventional breeding techniques with development of QPM. The opaque-2 mutation decreased the zein fraction and increases the non-zein protein fraction which is rich source of lysine and tryptophan. QPM possesses the required potential to improve the nutritional status of the poor populations and to serve as a vehicle for cost savings from expensive infant formulas and corn chips etc. Incorporation of Quality Protein Maize in food

✉ Navjot Kaur: navjot1667@gmail.com

[1]ICAR–Indian Institute of Maize Research, Punjab Agricultural University, Ludhiana, Punjab, India

[2]Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, Punjab, India

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and livestock feed is the most economical way to increase their protein quality as the amino acid composition of quality protein maize is superior than normal maize (Adom and Liu, 2002; Ruiz-Ruiz *et al.*, 2008; Carrillo *et al.*, 2007).

Maize Composition

The maize kernel is comprised of starch (@ 70 per cent), protein (@ 10 per cent), oil (@ 2–4 per cent) and vitamins and micronutrient. Maize occupied a well-deserved position as being a ‘poor man’s nutria-cereal due to high proportion of carbohydrates, proteins, fats and micronutrients. In the developing countries particularly in Africa and Latin America, several million people derive half of protein and approx. 56 per cent of energy requirements from maize because the protein from animal source is miserable and expensive for huge population. Maize germ oil obtained through wet milling posses’ potential application in salads dressing and cooking. Roasted maize kernels also possess application as substitute of coffee. Maize is also rich in phytochemicals or bioactive compounds mainly carotenoids (lutein, xanthophylls, zeaxanthin), phytosterols (sitosterol, stigmasterol, campestral) and phenolic compounds (ferulic acid and anthocyanin). Anthocyanins are water soluble pigments imparts reddish to purple colour to maize (Abdel-Aal *et al.*, 2006). Maize is considered as good raw material for the development of various industrial products such as starch, porridge, weaning foods, ethanol etc.

Quality Protein Maize

The quality of maize protein is poor as about 70 per cent maize endosperm protein (zein) is devoid of lysine and tryptophan. The protein quality of maize kernel was significantly improved with the development of a maize cultivar opaque-2. In 1963, Researcher at Purdue University (USA) found that maize mutants opaque-2 (op2) possess almost twice endosperm protein than present in normal maize. It is followed by the introduction of another mutant named *floury-2* (*fl2*). These mutants derive their names from endosperm characters like soft, opaque or floury (Carrillo *et al.*, 2004). The superior protein quality of high lysine mutant (*o2* and *fl-2*) recognized with undesirable traits as being susceptible to stresses and ear rot diseases. The chalky and soft endosperm prompt the inconsistency of grain which holds water content in it and causes harvest loss. These are the main limiting factors which restrict the adoption and utilization of mutants. By using conventional breeding techniques International Maize and Wheat Improvement Center (CIMMYT) improved the nutritional profile of maize through constant efforts and overcame the original opaque 2 defect. The new normal looking and tasting opaque 2 mutant were renamed as quality protein maize, a biofortified foods (Milind *et al.*, 2013). The amount of lysine and tryptophan in the maize endosperm protein is almost double in QPM varieties than in non-QPM or normal maize. Furthermore, it also raises the amount of amino acids like aspartic acid, glycine, arginine and histidine along with a decrease in the concentration of alanine, glutamic acid and leucine. A reduction in leucine concentration maintains the leucine and isoleucine ratio which helps in the liberation of tryptophan required for the synthesis of niacin. The comparative evaluation of nutritional components in QPM and normal maize is presented in Table 1.

Due to its better amino acid composition it is more economical to use diets incorporating QPM as it can lead to progressive reduction in the use of fishmeal and synthetic lysine additives**.** The amino acid composition of

Table 1. Comparison between chemical composition (a) and amino acid profile (b) of common and quality protein maize (Abiose and Victor, 2014)

A. Chemical composition

Components	Common maize	Quality protein maize
Protein (%)	9.80	9.72
Fat (%)	4.50	4.85
Ash (%)	1.62	1.50
Carbohydrate (%)	73.83	73.98
Sodium (mg/100 g)	61.65	43.88
Magnesium (mg/100 g)	141.30	137.10
Potassium (mg/100 g)	77.23	79.24

B. Amino acid profile of quality protein maize and normal maize

Amino acid (g/100 g of endosperm protein)	Ganga-5 (Normal)	Opaque-2		
		Shakti	Rattan	Protina
Lysine	1.88	4.07	3.76	3.68
Tryptophan	0.35	0.92	0.93	0.90
Leucine	14.76	9.19	9.72	9.26
Protein (%)	8.50	9.20	9.00	6.10

the meals from normal and quality protein maize shows that quality protein maize is superior to normal maize in terms of threonine (3.20 g/100 g), methionine (1.20 g/100 g), glutamic acid (7.50 g/100 g), isoleucine (2.74 g/100 g). The level of lysine in QPM (2.64 g/100 g) was higher than the level of lysine in common maize. Due to the nutritional benefits of QPM including high tryptophan and lysine levels, higher niacin bioavailability, calcium and carotene content and lower leucine content, its utilization can be explored for novel and conventional food products without the onset of their quality deterioration.

Utilization of quality protein maize for food purpose

Quality protein maize having high lysine and tryptophan content has been used in human nutrition and for feeding to monogastric animals which decreases the supplementation or fortification of feed and food material, respectively. Maize is the main staple food in Ghana where it has been reported that children fed with high lysine maize porridge gain weight and become healthier than children fed with common maize porridge (Ignjatovic-Micic *et al.*, 2008). The high level of lysine and tryptophan content increases biological value of QPM to almost double than normal maize. The nitrogen balance index for opaque 2 maize proteins and skim milk protein is 0.72 and 0.80, respectively, which describes that the protein quality of QPM is 90 per cent of that of milk protein. Research studies were conducted to evaluate the nutritional effect of QPM through feeding programs on human and animals (De Valenca *et al.*, 2017). It was revealed that consumption of QPM by infants as well as children increased the rate of weight gain and height by 12 per cent and 9 per cent, respectively (Emerson *et al.*, 1935). Although QPM is a nutritionally improved commodity, but its adaptability in the market is less, due to the lack of remunerative market price and interest in the maize food processors to popularize QPM products. QPM can be processed for the synthesis of a number of food products as follows:

Nixtamalized flour from quality protein maize

Alkaline treatment (lime) of maize kernel followed by steeping and washing to remove excess alkali is employed to obtain the product termed as Nixtamal and process is known as Nixtamalization. Nixtamal is ground to produce dough named Masa, a base ingredient to produce tortilla. It is an important step in the production of several maize products such as maize tortilla, tortilla chips, maize chips, flour, snacks and taco shells etc. Nixtamalization improves the nutritional quality particularly partial lipid saponification and starch gelatinization of product.

Carrillo *et al.* (2004) produced nixtamalized maize flour possessing acceptable physico-chemical and functional properties from QPM V-537 and determine the best nixtamalization process combination selected from nixtamalization variable that is time (20–85 min.), time of steeping (8 to 16 hours) and concentration of lime (3.3–6.7 g $Ca(OH)_2$/l). The optimum lime concentration, cooking and steeping time of nixtamalization to prepare nixtamalized flour were found to be 5.4 g, 31 min and 8.1 hours, respectively.

Temph flour

Solid state fermentation of boiled soybean, corn, wheat and groundnut using different *Rhizopus* spp. is employed to produce and improve the nutritional quality as well as palatability of traditional food namely Temph. These strains work by synthesizing enzymes to hydrolyze food constituents, reduce or eliminate anti-nutritional factor and to produce product with desired flavor and textural properties.

Rodrigue *et al.* (2004) evaluated and compared the nutritional and physico-chemical properties of unfermented QPM and QPM temph flour, soaking in acetic acid solution at 25ºC for 16 hr followed by cooking at 90ºC for 30 min and cooling at 25°C can be employed. Researchers reported that with solid state fermentation process, amino acid composition of product was improved as the content of histidine (0.81 g/100 g protein), isoleucine (0.52 g/100 g protein), leucine (1.46 g/100g protein), and tryptophan was increased ($p<0.05$). Fermented QPM flour with improved protein digestibility, protein efficiency ratio (2.10), PDCAAS (0.83), can be further found application for the fortification purpose to fortify different food products such as tortillas, bread, cookies etc. Inoculation of cooled grains can be done with *Rhizopus oligosporus*. This process also results in the reduction of antinutritional factors and increase in amino acid availability, protein digestibility.

Instant flour

Extrusion cooking is employed for the development of instant flour from QPM with little effluent problem as production of instant flour by nixtamalization process is time consuming and leads to high effluent waste. In extrusion cooking, various process variables such as screw speed, feed rate, feed moisture content, temperature, die shape and size, affect the properties of product. During extrusion cooking, over-gelatinization of starch reduces.

Moreno *et al.* (2003) developed instant flour with desirable functional properties using single screw extruder by mixing of maize grits (V 537) with alkali and to obtain moisture content up to 28 per cent. The process variables were temperature of extrusion process (70–100ºC), screw speed and concentration of lime that varied from 0.1–0.3 per cent and 30–80 rpm, respectively. The optimum extrusion conditions for the preparation of instant flour can be temperature 79.4ºC, lime concentration 0.24/100 g and screw velocity 73.4 rpm having highly acceptable physicochemical and functional properties.

Weaning food

Carrillo *et al.* (2007) determined the best proportion of chickpea and quality protein maize for preparation of weaning food and assessed the nutritional quality of developed product. The extrusion cooking of nixtamalized QPM and chickpea was employed at 79.4ºC and 150.5ºC at 73.5 rpm and 190.5 rpm, respectively. True protein and available lysine content of developed product was evaluated. It was reported that the most suitable combination of nixtamalized quality protein maize flour and chickpea flour was 21.2 per cent and 78.8 per cent, respectively. The final product contained 20.07 per cent protein content, 71.14 per cent carbohydrate content and covers amino acid profile except tryptophan, suitable for growth of infant.

Extruded Instant porridge

Extruded products with various shapes, flavours, textures and colours are developed in the food industry. The most widely consumed extruded products are made primarily with cereals/grains but they tend to have low protein quality and many other nutrients. Therefore, it is necessary to optimize the extrusion conditions for the development of nutritious extruded products. Kaur *et al.* (2019) optimized the extrusion process variables to develop and compare functional properties of normal maize and QPM based instant porridge. Independent variables such as moisture content, barrel temperature and screw speed were varied from 14–18 per cent, 125–175 °C, and 400–550 rpm, respectively. Carbohydrate, Protein solubility, hydration power and milk absorption capacity (MAC) were assessed using response surface methodology (RSM). It was reported that screw speed exhibited non-significant ($p \leq 0.01$; $p \leq 0.05$) affects on HP and CS while feed moisture and barrel temperature exhibited significant affect ($p \leq 0.01$; $p \leq 0.05$) on PS, HP and MAC. Optimum extrusion processing variables for development of QPM based porridge were ranged from 411.61–466.50 rpm screw speed, 14.19–15.36 per cent feed moisture at 150ºC. Study showed that extruded product can be developed from quality protein maize instead of normal maize without affecting functional properties of extrudates negatively.

Quality protein maize for feed purpose

For monogastric animals, complete protein sources are required for their growth and QPM plays an important in poultry feed and piggery. Utilization of QPM for feed purpose reduces the demand of protein supplementation up to 50 per cent and decrease the requirement to incorporate synthetic lysine. Maize is mainly used to as livestock feed because of its high energy, fibres and easy digestibility. But maize varieties are low in lysine and tryptophan content. So supplementations from other protein sources become necessary. The inclusion of QPM in the diet of monogastric animals and weaner pigs increases their weight and growth performance. Addition of QPM also reduces the cost of feed formulation by 5 per cent, this is very significant saving for developing countries (Groote *et al*., 2010).

Weaner pigs

Quality protein maize incorporation in feed formulation indicates an increase in weight of weaner pigs by 29.8 per cent (De-Quan and Shi-Huang, 1994) as compared to normal maize based feed. Addition of quality protein also reduces the cost of feed formulation by 5 per cent, this is very significant saving for developing countries.

Piglets at the initial stage of weaning requires more lysine and tryptophan as compare to growers and this situation leads to expensive supplementation by using commercial grade amino acids especially from soyabean meal.

Conclusion

Consumption of food with low nutritious value in terms of protein quality is mainly responsible for protein energy under nutrition which leads to morbidity and mortality of children. Advancement in technology continuously efforts which leads to the development of biofortified crops like QPM to reduce malnutrition in target countries. QPM possess a potential to reduce protein energy under nutrition in countries where population is solely depends on maize for their protein and energy requirements. But QPM has inbuilt drawback in terms of agronomic performance as compared to non-QPM varieties. Hence, there is need to introduce initiatives for improvement and adaptability of quality protein maize as potential food component.

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