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Peanut as a source of protein for human foods

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Abstract. Peanut has traditionally been used as a source of oil; however, its worldwide annual protein harvest has reached nearly 4.5 million tons. India followed by China and the United States are the major producers of peanut. In recent years, several cereals and legumes-based foods using peanuts as protein supplements have been developed to alleviate protein calories-malnutrition problem. Peanut in the form of flour, protein isolates, and meal in a mixed product have been found to be very desirable from a sensory quality point of view. Peanut protein is deficient with respect to certain essential amino acids, but its true digestibility is comparable with that of animal protein. Even though various processing methods influence the nutritional and sensory quality of peanut fortified human foods available information on these aspects have been reviewed and summarised in this paper in order to optimize the utilization of peanut protein to increase protein value of cereal-based foods in developing countries of the peanut growing regions of the world.

Introduction

Food crops have occupied an important place in human nutrition as they remain the major sources of calories and proteins for a large proportion of the world population, particularly, in the developing countries. For economic and social reasons, many millions of people in Asian and African countries depend on vegetable products largely cereals and legumes as sources of their dietary proteins. According to the latest FAO available data, about 80% of the proteins consumed by the humans in the developing countries are supplied by the plants and this trend has not changed in the past two decades or so [25]. Dietary deficiencies of protein and calories particularly among the preschool children and lactating women in the developing countries are still prevalent. The development of nutritionally balanced protein foods to feed the growing population in such countries is receiving increasing attention of the food scientists and nutritionists Several international agencies and governmental programs in developing countries are confronted with a challenging task of alleviating the so called protein-calories malnutrition problem. To overcome this problem to a large extent, principal raw materials, oil seeds and grain legumes are utilized to manufacture and market high protein foods at reasonably low prices. Several guidelines have been developed concerning formulation of food products consisting of various cereals fortified with concentrated protein sources such as defatted and full fat soy flour, non-fat dry milk, dry whey, dry butter milk, processed corn germ and wheat concentrate to alleviate malnutrition in developing countries. Several peanut and soy-fortified food blends have been utilized in food aid programs [19]. During the past decade, the research directions concerning evaluation of plant proteins as human foods have considerably changed and emphasis is being placed on designing protein blends of cereals and legumes to correct imbalances between amino acids from the nutritional point of view.

The peanut (*Arachis hypogeae* L.) also known as groundnut, earthnut, monkeynut, Manilanut and ground bean is the world's fourth most important source of edible vegetable oil and third most important source of vegetable protein [40]. About a decade ago, three excellent reviews were published on peanut protein and food uses of peanut [12, 40, 45]. In this paper, we intend to review and summarize the present status of peanuts as protein supplements to various cereal, legumes and root crops-based food products. It is not intended to be a comprehensive review on the subject, but efforts have been specifically made to review the relevant literature on the subject that appeared in the past decade. As a matter of convenience, the topic has been divided into five categories: 1) peanut protein production, 2) food uses of peanut, 3) peanut fortified foods and sensory quality, 4) nutritive value of peanut fortified foods, and 5) effect of processing on the nutritive value. Also, future research needs in specific areas have been highlighted.

Peanut protein production

The peanut protein production is primarily governed by the production of peanut in shell as peanuts are characterized by high oil and protein contents and a low percentage of carbohydrates and ash. Peanuts are grown and consumed in many countries in different continents as revealed by the world wide production data summarized in Table 1. Peanut is a native of South America and is grown on 20 million hectares in about 80 countries in the world. As shown in Table 1, the world peanut production is increasing and it has reached a new high of about 23 million tons (in-shell basis). This

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Table 1. Peanut and its protein production in the world

World country	Peanut in shell (million tons)		Peanut protein (million tons)	
	1979–81	1986–88	1979–81	1986–88
World	18·55	22·75	3·62	4·43
Africa	4·53	4·61	0·88	0·89
N & C. America	1·74	1·97	0·33	0·38
South America	0·98	0·71	0·19	0·13
Asia	11·22	15·38	2·18	3·00
Europe	0·02	0·03	—	—
Oceania	0·05	0·05	—	—
India	5·99	7·30	1·17	1·42
China	3·50	5·86	0·68	1·14

Source. FAO Production Year Book 1988 [26].

increase in peanut production has been achieved by increasing the harvested acreage and field per acre. There has been substantial increase in peanut yield during the last decade, although yield potential remained highly variable within some countries. However, peanut production worldwide has remained relatively stable in the 1970's ranging from 17 to 19 million tons annually [62]. India is the largest producer of peanut in the world averaging about 6 million tons annually. China followed by the United States and countries in Africa are next in order of importance so far as peanut production is concerned. India, China and the United States produce almost 60% of the world peanut crop.

Crude protein content of whole seed peanuts ranges between 22 and 30% (50). By applying the values of shell content 25% and nuts protein content 26%, total protein production of peanut was calculated as given in Table 1. It appears that nearly 4.5 million tons of peanut protein is harvested annually on a worldwide scale (Table 1). As it is true for the yield, India is the largest producer of peanut protein in the world, its peanut protein harvest is about 1.42 million tons followed by China with an annual peanut protein harvest of 1.14 million tons. Peanut proteins are consumed in the form of various foods as discussed below. Although peanuts are more popular for their oil content, processing of peanuts for oil extraction yields protein rich co-product which could also be used for human consumption.

Food uses of peanut

Among the major oil seed crops, peanut has some specific important advantages as it can be used in many food forms. With simple roasting and grinding process, peanuts can be converted into a variety of quality food

Table 2. Some important major food uses of peanut

Food Uses	Regions
1. Raw dry nuts	South and Central Asia, Africa
2. Fresh boild and salted	Southeast Asia, Africa
3. Fried and mixed with sugar syrup	Asia, particularly in India, Pakistan & Bangladesh
4. Fried and coated with chickpea flour	South Asia and Mediterranean regions
5. Nuts fermented and fried	Southeast Asia, particularly Indonesia, Phillipines & Thailand
6. Roasted and salted	Asia, Africa, N. & C. America & South America
7. Peanut butter	Europe, N. & C. America & South America
8. Candies and confections	N. & C. America, Some European, Asian and African Countries

products. Among the peanut eating people of the world, roasting and salting is the most preferred way of eating. Of the various ready-to-eat (RTE) foods of peanuts, roasted nuts are the most popular ones. About 60% of the peanuts harvested outside the United States are crushed and used for oil extraction while 70% of the United States crop is used for food purposes [40]. Some important food uses of peanuts in different regions of the world are listed in Table 2. In the United States, nearly 52% of the domestic edible peanut crop is used for peanut butter spreads, 23% for salted peanuts and 21% for confectionery [24]. Peanuts are sold fresh as a vegetable, canned frozen, roasted in the shell, toasted and salted, used in more than 50% confections are bakery products and are ground into butter for use in more than 100 recipes [62]. Results of a recent survey in some African countries indicated that peanuts were commonly used in the form of various food items such as roasted, ground (or paste), peanut oil, boiled or raw, the most commonly utilized form is the roasted peanut followed by peanut paste [54]. Extruded products of peanut meal and legume flour are also becoming popular as human foods in some African countries [55]. India, the largest producer of peanut, uses nearly 70% of the total production of peanut for oil extraction by screw or expeller pressing and the remaining amount is used as roasted, salted or fried nuts or as meal in various recipes.

Peanut fortified foods and sensory quality

In recent years, more efforts have been made to develop cereals and legumes – based foods using peanuts. Several such foods are summarized in Tables 3 and 4 and have been discussed in the following sections. From consumption viewpoint, the pleasant aroma, nutty flavor and desirable texture of the

Table 3. Some cereal, legume and root crops-based important food products using peanut

Principal Constituent	Product[a]	Peanut ingredient	Reference
Wheat	Chapatis	Peanut flour (20%)	34
Wheat	Bread	Peanut flour (12.5%)	28
Wheat	Noodle	Peanut flour (15%)	21
Corn	Epa-ogi	Peanut meal	4
Corn	Extrudates	Peanut meal (7%)	61
Millets	Laddus	Peanut meal (20%)	32
Corn	Nshima	Peanut meal (10%)	10
Sorghum	Kisra	Peanut flour (30%)	5
Sorghum	'Toe'	Peanut flour (15%)	33
Wheat — chickpea	Chapatis	Peanut flour (10%)	35
Wheat — cowpea	Bread	Peanut flour (20%)	55
Wheat — cowpea	Cookies	Peanut flour (35%)	55
Corn — oat	Snacks	Peanut grits (22%)	12
Wheat — soybean	Bread	Peanut flour (10%)	34
Corn — chickpea	Chapatis	Peanut flour (10%)	34
Cowpea	Akara	Peanut flour	52
Cassava	Gari	Peanut grits (10%)	23
Soybean	Tempeh	Peanut (20%)	13
Peanut	Oncorn	Peanut (100%)	14
Chickpea	snacks — chikki	Peanut	44

[a] Most of the products are mentioned by their local/regional names.

Table 4. Some important bakery, beverage and confectionery food products using peanut

Principal Constituent	Product	Peanut ingredient	Reference
Wheat	Biscuits	Peanut flour (50%)	48
Wheat	Biscuits	Protein isolate (22%)	48
Wheat	Marzipan	Peanut paste	17
Millets	Biscuits	Peanut flour	60
Wheat — cowpea	Cake	Peanut flour (10%)	41
Ragi — soybean	Biscuits	Peanut flour	60
Sorghum — chickpea	Candles	Roasted peanuts	8
Peanut	Muffin	Peanut flour (100%)	48
Corn	Muffin	Peanut milk	15
Whey	Chocolate shake	Peanut (8%)	46
Carob milk	Cup confection	Peanut concentrate	24
Peanut	Ice cream	Protein isolate	27
Buffalo milk	Ice cream	Protein isolate	27
Peanut	Beverage	Partially defatted	54
Peanut	Panned product	Peanut meal	7
Whey	Shake	Peanut solids	46
Beef	Sausage	Peanut meal (20%)	29
Peanut	Crunch	Roasted peanuts	53
Sweet potato — soybean	Cake	Peanut flour (10%)	1

raw and roasted nuts are the unique features of peanuts that place them above all other edible grain legumes. Different combinations and concentrations of peanut in a mixed product influence the sensory quality of the product. Several such instances have been quoted and optimum concentrations of protein isolate, peanut flour and peanut meal found satisfactory by sensory evaluation of the food products have been mentioned in Tables 3 and 4. According to Khan et al. [37], peanut protein concentrates (PPC) higher than 10% reduced loaf volume of bread significantly compared to that of bread baked with other protein sources. Abdel et al. [1] reported that 10% of peanut, 30% sweet potato, and 15% soybean flours in combination with wheat flour produced acceptable cake. Further, they noticed that laboratory prepared flours containing 15% of peanut, soybean and sweet potato in place of wheat flour also did not affect the cake quality [1]. The industrially processed oil seed proteins and isolates including that of peanut were found suitable for baking properties [36].

A cake-type recipe was prepared by using cowpea-wheat and peanut meal (30%) untoasted and it was concluded that peanut of cowpea meal was suitable for inclusion in such doughnuts but reduction of meal particle size and inclusion of soy flour to reduce fat absorption during frying were recommended [41]. While describing methods of producing a slurry from peanuts and crop foods such as soybeans or peas, it was reported that heating of slurry followed by rapid cooling prevented damage to protein content and produced desirable flavor of peanut for various food formulations [28]. Confections with peanuts have been the subject of several studies in the past. Riedel [53] described recipes using roasted peanuts which can be made and sold throughout the year including peanut cubes or bars, peanut crunch and coated peanuts. Manufacture of soft-panned confectionery products with particular reference to soft-panned groundnuts was described as a typical example [7]. A chocolate-flavored shake-type beverage containing 84% whey and 8% peanuts has been developed by soaking peanuts in sodium bicarbonate solution overnight to develop desirable flavor before being incorporated into a whey slurry [46].

The development of cereal-based foods using peanut has received considerable attention in the recent years. Khalil et al. [34] conducted organoleptic evaluation of wheat bread supplemented with peanut flour and found that bread containing 20% peanut flour was best with respect to organoleptic properties. Axer [11] obtained comparable sensory evaluation results on almonds and peanut butter for 8 bakery formulations. The development of neutral flavored high stability peanut paste for use as an extender to bakery and marzipan products was reported by Black [17]. Maize extrudates were prepared with improved structure by addition of finely comminuted peanuts [61]. Temperature and moisture of the extrusion process greatly influenced the texturization and sensory quality of peanut products [2]. Lil and Chang [39] studied the relationship between texture and chemical components of peanuts after precooking and found that cooking improved texture and shear press, but values declined on longer cooking. Peanut supplemented Chinese type noodles were prepared from blends of durum wheat flour and partially defatted peanut flour and it was observed that replacement up to 15% of wheat flour with peanut flour resulted in noodles with acceptable sensory qualities [21]. Further, addition of peanut most favorably affected the flavor of porridge and nshima, two traditional Zambian corn based cereal dishes [10].

Nutritive value of peanut-fortified foods

Like other grain legumes, the nutritive value of peanut proteins is also a function of its protein content, amino acid composition, and protein digestibility. As reported above, protein content of peanuts ranges between 15.4 and 30.2% showing a large variation which is greatly influenced by genotypes and environments. Peanut flour which is most commonly used for fortification contains protein ranging from 47.0 to 55.0% with mean being 50.0% [41]. Protein isolates and protein concentrates contain higher amounts of proteins depending on the methods of preparation. Peanut protein concentrates had crude protein 70.2% but it had an unbalanced amino acid pattern and was deficient in lysine threonine, methionine and tryptophan [38]. Peanut proteins are generally considered to be of low nutritional quality because several of the essential amino acids are present in limited amounts, e.g., lysine, tryptophan, threonine and sulphur containing amino acids as shown in Table 5. Protein efficiency ratio (PER) and relative nutritive value (RNV), as indices of protein quality of peanut flour were comparable with that of soybean protein isolates (Table 6). It is also evident from the data reported in Table 6 that the nutritive value of peanut protein is much better than the wheat protein (Bodwell, 1979). A comparison of true digestibility indicated that protein digestibility of peanut flour was better than that of the soy flour and it was comparable with the animal protein digestibility (Table 7). According to Mitchell [31], the protein quality in terms of PER values of soy protein isolates, peanut (flour), and single cell proteins were 72%, 56% and 66% respectively.

Fortification of cereals with legumes has resulted in improving the nutritional quality of human dietary proteins. Khalil et al. [34] observed that PER and net protein utilization (NPU) of wheat breads were significantly

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Table 5. Essential amino acid (g/100 g protein) composition of peanut protein products

Amino acid	Peanut kernel	Peanut flour	Protein concentrate	Protein isolate	FAO pattern
Lysine	3·5	4·0	2·9	3·0	5·5
Leucine	6·4	6·4	6·8	6·4	7·0
Valine	4·2	5·3	4·7	4·4	5·0
isoleucine	3·4	3·2	3·5	3·5	4·0
Threonine	2·6	2·6	2·5	2·4	4·0
Phenylalanine	5·0	4·7	5·5	5·4	—
Tyrosine	3·9	3·7	4·1	4·4	—
Total sulphur amino acids	2·5	1·9	2·5	2·7	3·5
Cystine	1·3	1·0	1·4	1·8	—
Methionine	1·2	0·9	1·1	0·9	—
Tryptophan	1·0	1·0	0·9	0·8	1·0

Source: Reference [45].

increased due to supplementation with peanut flour. Ory and Conkerton [48] reported that muffins made of wheat and peanut flours contained 33–40% protein and can serve as a high-protein snack foods or bakery items. Data presented on the characteristics of peanut flours used in protein fortification have revealed considerable improvement in protein quality of three Nigerian foods: chin-chin, puff-puff and akara [52]. PER value of sorghum flour when supplemented with cowpea soy flour and peanut flour was 2.37 comparable with casein protein and essential amino acid patterns comparable with FAO values [47].

In another study, children fed with peanut fortified millet and rice diets experienced greater height and weight growth, greater arm and chest development and higher hemoglobin concentration levels than control children who were not fed these diets [22]. By using chicks as test animals, nutritional evaluation of bread-enriched with peanut proteins revealed that

Table 6. Relative protein nutritive value and protein efficiency ratio of different protein breads[a]

Protein source (breads)	Rat bioassay				Relative value in humans
	RPV	NPR	PER	C-PER	
Peanut flour	52	61	1·59	1·67	79
Soy protein isolate	47	70	1·77	2·48	77
Wheat gluten	25	32	0·45	0·69	75
Egg white	100	100	2·83	2·94	100

[a] Source: Reference [18].

Relative protein value (RPV, net protein ratio (NPR), protein efficiency ratio (PER), calculated (C-PER).

Table 7. True digestibility by adults of peanut proteins in comparison with other common proteins

Protein source	Number of Reports	Digestibility (%)	
		Mean	Range
Peanut flour	4	94	91–98
Soy flour	5	86	75–92
Soy isolate	3	95	93–97
Animal protein	41	96	90–106

Source: Reference [30].

peanut flour improved the protein quality and was as good a substitute as peanut protein isolate or peanut protein concentrate [58]. The nitrogen balance of 6 adult human subjects fed on maize bread alone and bread supplemented with 20% peanut flour was significantly improved with supplementation [35] suggesting that fortification of maize bread with peanut flour will enhance the nutritive value of maize bread for adult human subjects. When fed with food product of maize and peanut mixtures (Epa-Ogi), children gained more weight than the control diet indicating the better protein quality of the product studied (Afolabi et al., 1988). In vitro protein digestibility (IVPD) of wheat flour was 30% and it increased to 40% when supplemented with peanut meal showing a considerable improvement in protein digestibility (Brule and Savoie, 1988). A considerable improvement in protein, lysine and IVPD of sorghum-based kisra, a fermented unleavened bread, was observed when it was supplemented with peanut flour [5].

Effect of processing on nutritive value of peanut-fortified foods

Various processing treatments affect the nutritive value of plant foods. Heating and fermentation process are among the most commonly used processing practices for preparation of human foods. Several antinutritional factors such as flatulence causing sugars, stachyose and raffinose, and metal binding compound, phytic acid were significantly reduced due to fermentation of peanuts, a process involved in 'oncom' preparation [25]. Miso-like fermented product containing soybean and peanut contained more soluble nitrogen and had little effect on accumulation of free amino acids. Fermentation of partially defatted peanut flour for preparation of 'tempeh' resulted in more free lysine, methionine and soluble nitrogen, desirable changes from nutrition point of view (Bhavanisankar et al., 1987). Peanut proteins undergo changes due to heating or roasting of the seed and removal of the oil from the seed. Ory et al. (49) summarized the effects of dry roasting

(145°C for 60 min) and found that solubility of proteins was reduced by about 50%. Boiling and frying improved protein quality in terms of PER, NPU and IVPD values, but NPU was reduced on roasting of peanuts [9]. Acton et al. [3] reported that processing by drum drying and partial defatting increased PER to high of 1.91 as compared to PER of 1.43 of starting material. No significant losses of amino acids due to autoclaving of peanuts for 5 min at 120°C were observed [59]. Trypsin inhibitors of grain legumes interfere with protein digestibility. Mostafa [43] studied the effect of various heat treatments and irradiation to inactivate these antinutritional factors and improve IVPD of peanuts. Dry heat (100–120°C for 1 h) and autoclaving at 121°C for 30 min did not completely inactivate, whereas roasting at 160°C for 1 h did destroy trypsin inhibitors of peanuts. According to Alid et al. [6] extrusion process causing texturization of peanut proteins did not have any significant effects on amino acid patterns nor on the PER value of peanut flour. However, extrusion of a fully defatted peanut flake to produce a textured granule reduced PER from 1·91 to 1·70 and also raw and heat processed peanut flours were found to contain higher in vitro trypsin inhibitors activity and lectins than similarly processed soy flour [57]. Trypsin inhibitors of grain legumes are generally destroyed by heat treatment. It was observed that peanut trypsin inhibitors were destroyed by heating at 100°C for 91 min and at 120°C for 9·3 min [51]. When peanuts are roasted, the sugars and free amino acids react to produce the typical roasted peanut color, flavor and aroma [62]. This would also affect the sensory quality of some fortified and processed foods using peanuts. All variable results have been obtained as a result of processing practices on the nutritional composition of peanuts. Additional efforts to standardize the optimum conditions to derive maximal nutritional advantages would be useful in this direction.

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