

Research Article

Effect of incorporation of decorticated pigeon pea (*Cajanus cajan*) protein isolate on functional, baking and sensory characteristics of Wheat (*Triticum aestivum*) biscuit

¹H. A. Hassan, ²A.I. Mustafa and ³A.R. Ahmed

¹Food Research Centre, P.O. Box 213, Khartoum North, Sudan

²Department of Food Science and Technology, University of Khartoum, Sudan

³Ahfad University for Women, P.O. Box 167, NCTR, Omdurman, Sudan

Abstract: This study was undertaken with the objectives of using the decorticated pigeon pea protein isolate in the development of protein rich-biscuit, suitable for general and specific nutritional purposes and to study the effect of incorporation of pigeon pea protein isolate on the sensory evaluation and quality of biscuit produced. Decorticated Pigeon Pea protein Isolate (DPPI) was incorporated in wheat (*Triticum aestivum*) flour (WF, extraction rate 72%), for making fortified biscuit. Ratios of DPPI in wheat flour were adjusted to protein levels of 15, 20 and 25%, respectively. Rheological and functional properties as well as proximate composition, nutritive value and sensory characteristics for the biscuit produced were assessed. The gluten quantity (dry and wet) and falling number of wheat flour were significantly ($p \leq 0.05$) decreased with the incorporation of DPPI from 10.25 to 7.6%; from 31.2 to 22.5% and from 657 to 443 sec., for 0, 15, 20 and 25% protein levels, respectively. Water Retention Capacity (WRC), Bulk Density (BD) and Fat Absorption Capacity (FAC) were obtained. Addition of DPPI resulted in an increase in water absorption which was found to be ranged from 66.7 to 71.0%; dough development time from 4.5 to 7.3 min and dough stability 1.7 to 5.8 min. Biscuit supplemented with DPPI showed significant increase ($p \leq 0.05$) in ash, protein with high level of incorporation and significant decrease ($p \leq 0.05$) in carbohydrates and caloric values when biscuit wheat was supplemented with high level of DPPI. Incorporation of DPPI showed no significant differences ($p \leq 0.05$) on biscuit spread ratios compared to wheat biscuit (control). Biscuit with 15% protein level was found to be superior in all its sensory characteristics compared to the other blends.

Keywords: Membrane bio-reactor, membrane separation, micro electrolysis, waste emulsion

INTRODUCTION

Among ready-to-eat snacks, biscuits and cookies possess several attractive features including wider consumption base, relatively long shelf-life, more convenience and good eating quality (Akubor, 2003; Hooda and Jood, 2005). Long shelf-life of biscuits makes large scale production and distribution possible. Good eating quality makes biscuits attractive for protein fortification and other nutritional improvements. Development of fortified biscuits or other composite flour bakery products is the latest trend in bakery industry (Baljeet *et al.*, 2010). The growing interest in these types of bakery products is due to their better nutritional properties and possibility of their use in feeding programs and in catastrophic situations such as starvation or earthquakes (Pratima and Yadava, 2000).

Pigeon pea (*Cajanus cajan* L.) is economically and nutritionally important legume as major source of

proteins in poor communities of many tropical and subtropical regions of the world (Singh *et al.*, 1984). Legumes represent a major source of nutrients, including valuable but incompletely balance protein, particularly in vegetarians' diet (Ghadge *et al.*, 2008). Legumes, which belong to the group of protein rich vegetable foods, are particularly rich in the amino acid lysine, yet are usually deficient in the sulfur-containing amino acids like methionine. It has been estimated that the total production of legumes provide almost as much protein (20-30%) to the world as wheat and over 50% more than rice or corn (Gopalan *et al.*, 1985). In addition, legumes supply significant amount of energy through carbohydrates (60- 70%), lipids (1-7%), dietary fibers and minerals (2-5%), also the legume oilseeds contains reasonable levels of thiamine, riboflavin and niacin (Bressani and Elias, 1974). In spite of the nutritional potential of the legumes, they are underutilized as food.

Corresponding Author: Xin-dong Li, Architectural and Mapping Engineering School, Jiangxi University of Science and Technology, Ganzhou, China

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

In India, several seed legumes have been traditionally supplement (either in the form of splits (Ghadge *et al.*, 2008) or whole legume) with staple cereals (cooked rice, chapattis and poories) (Kachroo, 1970). Legumes and cereals have complementary nutritional effects and their consumption together fulfils the need of balanced protein. The nutritive value of legumes depends upon the processing methods, presence or absence of antinutritional or toxic factors and possible interaction of nutrient with other food components. Legumes as a supplement bring to cereal-based diets a variety of taste and texture. Availability of certain technologies with respect to pigeon pea processing (e.g., decortication, protein concentration and isolation....etc) encourages the use of these legumes in fortification of cereal-based products.

Pigeon pea, (known locally as "Lubia Addassy") is traditionally grown in North and Central Sudan as a very minor crop. The popular variety of pigeon pea in Sudan is the brown colored seeds of long duration. Pigeon pea protein is a rich source of lysine, but is usually deficient in sulphur-containing amino acids, methionine and cystine; it thus supplements the essential amino acids in cereals as reported by Gopalan *et al.* (1971). Pigeon pea improves the amino acid scores for lysine in rice and wheat-based diets; and for threonine, leucine, and isoleucine if the proportion of pigeon pea in the diet is increased to 70:30 cereals: pigeon pea (Gopalan *et al.*, 1971). Daniel *et al.* (1970) found that incorporation of 8.5% pigeon pea dhal in a rice diet, and 16.7% in a finger millet diet improved the diets' nutritive value. Mustafa *et al.* (1986) improved the nutritive value of cookies and bread by adding cowpea protein isolate to raise wheat flour protein to 15 and 20%. Pigeon pea has rarely been used in baked foods and confectionary products. Bakery products in the Middle East especially in the Arab countries consider an important source of nutrients i.e., energy, protein, minerals and vitamins. Most bakeries products can easily be enriched and fortified at low cost with proteins, vitamins and minerals to meet specific needs of the target groups of the population (Indrani *et al.*, 2007). Rheological properties of dough can be used as quality indicators for cereal products (Asghar *et al.*, 2009). This fact has contributed to use rheological testing for following the changes in dough systems and mechanical properties.

In general, the biscuit making potential increases in its nutritional characteristics with increasing levels of incorporation of DPPI. The method of preparation can increase or diminish the functionality of protein isolates in biscuit dough's. Bloksma and Bushuk (1988) stated that the characteristics of the dough are depending on the type of flour, quality and quantity, ingredients used and mixing conditions. Hosene and Rogeres (1993) reported that the wheat flour dough is able to retain gas,

which is essential for production of baked products with a light texture.

MATERIALS AND METHODS

Materials: Australian wheat flour for biscuit making was obtained from a local Flour Mill in Khartoum North. Pigeon pea (*Cajanus cajan* L.) brown colored seeds were purchased from the local market during the harvesting season of 2002/2003. The whole experiment was carried out at the Food Research Centre, Khartoum North, Sudan. The added ingredients used in processing i.e., leaving agents, salt, sugar, shortening and skimmed milk were purchased from the local market. Pigeon pea was decorticated into its dicotyledons (dhal/splits), according to the methods of Hassan and Bureng (1996). The clean decorticated pigeon pea seeds were ground into flour using an efficient pulverizer (80-100 mesh). Decorticated pigeon pea protein isolate was prepared according to the method of Mustafa *et al.* (1986).

Decorticated pigeon pea protein isolate and wheat flours blends were prepared in such a way that DPPI replaced WF to adjust the protein levels to 15, 20, and 25%, respectively. All the blends prepared were used for the different analysis. The anti-nutritional factors, namely tannins were determined according to the method of Price *et al.* (1978) and phytic acid was determined according to the method of Wheeler and Ferrel (1971).

Rheological properties of WF and the blends were determined according to the AACC (2000) standard methods, falling number (" -amylase activity) according to the method AACC No56-81 B (2000), gluten quality and quantity according to the Standard method of AACC 158(2000), Farinograph characteristics according to the method No.54-10 (2000). Functional properties of WF and composite flours i.e. Water Retention Capacity (WRC) according to Quinn and Beuchart (1975); Fat Absorption Capacity (FAC) according to Lin *et al.* (1974) and bulk density according to Wang and Kinsella (1976).

Biscuits were made according to Vastala and Haridis (1991). The biscuits produced were assessed organoleptically according to the Scoring (hedonic) scale of 5 points procedure described by Ihekoronye and Ngoddy (1985). Fifteen semi-trained assessors were provided with coded samples and asked to evaluate the general appearance, flavor taste, texture and overall quality of the biscuits. A key Table 8 was given to the panelists as a guide to score according to. The biscuit quality was evaluated for biscuit weight; spread ratio and sensory characteristics.

Data generated was subjected to the Statistical Package for Social Sciences (SPSS). Means were tested using One-Factor Analysis of Variance, and then separated using Duncan's Multiple Range Test (Mead and Gurnow, 1983).

Table 1: Proximate composition of raw materials (on dry matter basis)

Types of flour	Moisture (%)	Ash (%)	Protein*	Fat (%)	Tannins Mg/100g	Phytic acid	CHO**(%)
Wheat Flour (WF)	11.53	0.63	13.23	1.50	ND	ND	73.07
Whole Pigeon pea Flour (WPF)	9.53	3.96	22.55	2.13	0.13	127.96	61.73
Decorticated Pigeon pea Flour (DPF)	8.50	3.73	23.23	2.07	0.03	68.55	62.47
Decorticated Pigeon Pea protein Isolate (DPPI)	5.80	2.78	81.12	ND	ND	ND	ND

*: Factor of wheat flour N x 5.7 and for pigeon pea N x 6.25; **: Values calculated by difference; ND: Not determined

Table 2: Functional properties of biscuit wheat flour as affected by inclusion of DPPI

Flour blends*	Bulk Density(BD)	Water Retention Capacity (WRC) (g/100g)	Fat Absorption Capacity (FAC)(g/100g)
100% WF (Control)	0.517±0.02 ^d	140±0.00 ^a	80±0.00 ^d
WF + DPPI (15% protein)	0.568±0.02 ^b	140±0.00 ^a	95±5.00 ^b
WF + DPPI (20% protein)	0.578±0.00 ^c	140±0.00 ^a	90±10.00 ^c
WF + DPPI (25% protein)	0.625±0.00 ^a	135±5.00 ^b	100±0.00 ^a

#Mean values (±SD) having different superscript letters in each columns differ significantly (p#0.05); WF: Wheat flour; DPPI: Decorticated pigeon pea protein isolate

Table 3: Falling number, gluten quality and quantity of wheat flour intended for biscuit making as affected by inclusion of DPPI

Flour blends	Falling number(Sec.)	Gluten (%)		
		Wet gluten	Dry gluten	Gluten index
100% WF (Control)	657.33±7.57 ^a	31.20±0.20 ^a	10.25±0.05 ^a	80.29±0.02 ^a
WF + DPPI (15% Protein)	515.67±7.51 ^b	29.20±0.20 ^c	9.50±0.50 ^{bc}	73.57±0.93 ^c
WF + DPPI (20% Protein)	478.00±12.0 ^c	27.15±0.15 ^d	9.22±0.20 ^c	76.50±0.50 ^b
WF + DPPI (25% Protein)	443.00±1.00 ^e	22.50±0.50 ^f	7.60±0.20 ^d	66.6±0.50 ^d

RESULTS AND DISCUSSION

Proximate composition of the flours: The proximate composition of Wheat Flour (WF), whole seeds of pigeon pea (WPF), Decorticated Pigeon pea Flour (DPF) and Decorticated Pigeon Pea protein Isolate (DPPI) are shown in Table 1. Wheat flour was found to contain 88.47% dry matter, 0.63% ash, 13.23% protein, 1.50% fat, 73.07% carbohydrates on dry matter basis. These results appear to be in agreement with those reported previously by Pyler (1973), Kent-Jones and Amose (1967), Schruben (1979) and Eltoum (2004). On the other hand the whole seeds of pigeon pea, decorticated pigeon pea flour and DPPI were found to be 90.47, 91.50 and 94.20% dry matter; 22.55 and 23.23 and 81.12% protein; 3.96, 3.73 and 2.78% ash, respectively. The fat and carbohydrates contents for whole pigeon pea and decorticated pigeon pea flours were found to be 2.13 and 2.07%; 61.73 and 62.47%, respectively. Mohammed (2002) reported values of 3.63 and 3.37% ash, 19.88 and 21.62% protein and 2.41 and 2.07% fat for whole and decorticated pigeon pea flour, respectively. Decortication of pigeon pea seeds resulted in an increase of protein and carbohydrates and reduction of fat and ash. These results were in agreement with the results obtained by Mohammed (2002). The antinutritional factors i.e., tannins content of un-decorticated pigeon pea was found to be 0.13 mg/100 gm, while decorticated pigeon pea gave a value of 0.03 mg/100 gm material. Similar values were reported by Singh (1988) for ten cultivars, and also Mohammed (2000) obtained similar results. On the other hand values of phytic acid results for whole and decorticated pigeon pea were found to be 127.96 and

68.55 mg/100 g (DM), respectively. Decortication has been reported to eliminate tannins; commonly known as polyphenols (Rao and Deothale, 1982) and also reduce the amount of phytates (Lasztity and Lasztity, 1990)

Functional properties of wheat flour as affected by inclusion of DPPI: Table 2 Shows the effect of addition of DPPI on the functional properties of wheat flour for biscuit making. The Bulk Density (BD) of the wheat flour was found to be 0.517. This value was significantly increased to 0.568, 0.578 and 0.625 for 15, 20 and 25% protein levels, respectively. High bulk density is a desirable characteristic when powdered food materials of high nutrients content are to be packed in a limited space. The Water Retention Capacity (WRC) of WF was found to be 140 mL/100 g. Incorporation of DPPI showed no significant differences (p#0.05) and same values of WRC were found for WF (140 mL/100 g). Lower value of WRC was obtained for DPPI protein level 25% (135 mL/100 g). On the other hand, the Fat Absorption Capacity (FAC) of WF was found 80 mL/100 g. Incorporation of DPPI resulted in a significant increase in FAC and values obtained were 95, 90, and 100 mL/100 g for 15, 20 and 25% protein level, respectively. These increases may be attributed to the increase of hydrophobic groups on the surface of the protein molecules.

Rheological properties of the dough's: Gluten quantity (wet and dry) and gluten quality (gluten index) of dough's prepared from DPPI with WF are presented in Table 3. Incorporation of DPPI in WF gave significant decrease (p#0.05) in values (29.20, 27.15,

Table 4: Farinogram of doughs prepared from wheat flour and composite flour

Flour blends	Water absorption (%)	Dough development time (min)	Dough stability	Degree of softening (FU)	Farinograph quality No. (min)
100% Wheat flour (WF)	63.7	6.7	10.1	21	118
WF + DPPI (15% protein)	66.7	4.5	5.8	58	76
WF + DPPI (20% protein)	69.5	7.3	1.9	47	90
WF + DPPI (25% protein)	71	6.8	1.7	69	80

Table 5: Spread ratios of wheat biscuit as affected by inclusion of DPPI

Flour blends	Width (cm)	Thickness (cm)	Spread ratio (width/thickness)
100% Wheat flour (WF)	5.238±0.11 ^d	0.871±0.07 ^d	5.849±0.25 ^a
WF + DPPI (15% Protein)	5.317±0.18 ^c	0.924±0.04 ^c	5.758±0.23 ^a
WF + DPPI (20% Protein)	5.411±0.11 ^b	0.969±0.07 ^a	5.606±0.38 ^a
WF + DPPI (25% Protein)	5.466±0.14 ^a	0.931±0.05 ^b	5.809±0.24 ^a

#Mean values (±SD) having different superscript letters in the same column differ significantly (p#0.05); WF: Wheat flour; DPPI: Decorticated pigeon pea flour

Table 6: Chemical composition and energy values of wheat biscuit containing DPPI

Types of flour	Dry matter (%)	Ash (%)	Protein* (%)	Fat (%)	CHO (%)	Caloric values (kcal/100g)
100% Wheat flour (WF)	96.09a	0.917d	13.62d	14.20d	67.31a	449.4b
WF + DPPI (15% protein)	96.19a	1.049cb	15.62c	14.70a	64.83b	450.6a
WF + DPPI (20% protein)	96.01a	1.080b	20.60b	14.52b	59.81c	447.7c
WF + DPPI (25% protein)	95.94a	1.179a	25.75a	14.48bc	54.53d	445.5d

#Mean values (±SD) having different superscript letters in the same column differ significantly (p#0.05); WF: Wheat flour; DPPI: Decorticated pigeon pea protein isolate

and 22.50%) of wet gluten for 15.20 and 25% protein levels, respectively, compared to 31.20% for WF (control). Significant decrease (p#0.05) was also observed in dry gluten and gluten index.

The falling number value (alpha-amylase activity) of WF was found to be 657 sec. Increasing levels of DPPI in WF resulted in a significant decrease (p#0.05) in the falling number (high alpha-amylase) which decreased from 515, to 478 and to 443 sec. (Table 3). Alpha-amylase may be added to wheat flour to achieve any desired level of enzyme activity. The optimum level of enzyme activity is ultimately governed by the end use of the flour and the type of processing involved as mentioned by Mailhot and Patton (1988).

Farinogram of doughs prepared from wheat flour and composite flour: Incorporation of DPPI in wheat flour affected the dough development time and gave highest value of 7.3 min for protein level of 20% and lowest value of 4.5 min for 15% protein level (Table 4). The dough stability of 10.1 min for wheat flour tended to decrease with the addition of DPPI to the values ranged from 5.8 to 1.9 and to 1.7 min. The degrees of softening for different protein levels were found to be 58, 47 and 69 for 15, 20 and 25%, respectively. Higher value of Farinograph quality number 188 min for wheat flour, these values was decreased to 76, 90 and 80 min for 15, 20 and 25% protein levels, respectively.

Physical and chemical characteristics of biscuit:

Biscuit spread ratio: The effect of DPPI on the physical characteristics i.e., width (cm), thickness, (cm) and spread ratio of wheat biscuit are shown in Table 5. Incorporation of DPPI resulted in an increase in biscuit width from 5.238 for WF, to 5.317, 5.411 and 5.466 cm

for 15, 20, and 25% protein levels in the blends, respectively. Statistical analysis showed no significant differences in spread ratios of biscuit from wheat flour and composite flour blends. The spread ratio of biscuit decreased, as the DPPI increased. The values ranged from 5.758 cm for 15% protein level to 5.809 cm for 25% protein level.

Chemical composition and energy evaluation:

Values of ash were found to be increased by the addition of DPPI and no significant differences were noticed between 15% (1.049%) and 20% (1.080%) protein levels. Also increasing levels of DPPI resulted in a significant increase in protein and values obtained were found to be 15.62, 20.60 and 25.75% for 15, 20 and 25% protein levels, respectively. Significant decrease of carbohydrate and calorific values were also observed for supplemented biscuit; from 64.83; 450.6 to 59.81; 447.7 and to 54.53; 445.5 for 15, 20 and 25 protein level, respectively (Table 6). The results obtained above were in agreement with those reported by Sulieman *et al.* (2003) who reported that supplemented cookies with cow pea increased ash, proteins and fat with increasing levels of replacement.

Sensory evaluation of wheat biscuit with addition of DPPI:

Incorporation of DPPI did not significantly affected the color, up to protein level of 20% (Table 7). Significant decrease was observed in protein level of 25% and lower scores in color were obtained (2.3). Odor and after taste were not significantly affected by supplementation of DPPI in 15 and 25% protein level in the blends. High scores were found in the blend of 25% protein level in after taste and texture, and these may be attributed to the reaction with carbohydrate and high proteins (Carmalization and Millard reaction effect).

Table 7: Sensory evaluations of wheat biscuit containing pigeon pea protein isolate

Flour blends*	Color	Odor	After taste	Texture	Overall quality
100% Wheat flour (WF)	3.9a	3.9a	4.2a	4.3a	4.1a
WF + DPPI (15% protein)	3.5a	3.8a	3.7a	3.7b	3.6b
WF + DPPI (20% protein)	3.8a	2.7b	2.7b	3.4c	2.8c
WF + DPPI (25% protein)	2.3b	3.9a	4.4a	4.5a	3.5b

Mean values (±SD) having different superscript letters in each columns differ significantly (p#0.05); *WF: Wheat flour; PPPI: Pigeon pea protein isolate

Table 8: Table of description

Color	Odor	After taste	Texture
Golden brown (5)	Desirable (5)	Pleasant (5)	Crispy (5)
Uniformity (4)	Normal (3-4)	Normal (3-4)	Hard (3-4)
Brownish (3-3)	Off flavor (1-2)	Off taste (1-2)	Brittle (1-2)

From the results obtained above; it was observed that biscuit made from the blend (20% protein level) was rated inferior to the control, biscuit made from blends of 15 and 25% were still within the acceptable range.

CONCLUSION

It was concluded from the results that inclusion of DPPI in cookies at specific level can be carried out successfully without any noticeable changes in desirable organoleptic properties of the end products, but better process methods may be needed to maintain quality. Such high-protein cookies could be given to children in drought areas to combat malnutrition. The children of these areas are already acquainted with the pigeon pea flour taste; however, proper formulation should resolve undesirable changes.

REFERENCES

AACC, 2000. Approved Methods of the American Association of Cereal Chemists. 17th Edn., St. Paul. MN. USA.

Akubor, P., 2003. Functional properties and performance of cowpea/plantain/wheat flour blends in biscuits. *Plant Food Hum. Nutr.*, 58: 1-8.

Asghar, A., F.M. Anjum, J.C. Allen, C.R. Daubert and G. Rasool, 2009. Effect of modified whey protein concentrates on empirical and fundamental dynamic mechanical properties of frozen dough. *Food Hydrocolloid.*, 23: 1687-1692.

Baljeet, S.Y., B.Y. Ritika and L.Y. Roshan, 2010. Studies on functional properties and incorporation of buckwheat flour for biscuit making. *Int. Food Res. J.*, 17: 1067-1076.

Bloksma, A.H. and W. Bushuk, 1988. Rheological and Chemistry of Dough. In: *Wheat Chemistry and Technology*, Pomeranze, Y.E., (Ed), Amer. Assoc. Cereal Chem., St. Paul, MN.

Bressani, R. and S.G. Elias, 1974. Nutritive Value of Legume Crops for Humans and Animals. *Advances in Legume Science*. Summerfield, R.J. and A.H. Bunting, Royal Botanical Gardens, London, pp: 135.

Daniel, V.A., D. Narayanaswamy, B.L. Desai, S. Kurien, M. Swaminathan and H.A. Parpia, 1970. Supplementary value of varying levels of red gram (*Cajanus cajan*) to poor diets based on rice and ragi. *Ind. J. Nutr. Diet.*, 7: 358-362.

Eltoum, S.H., 2004. Utilization of gongolase and guddiem as functional foods in bread and biscuit making. M.Sc Thesis, University of Khartoum.

Ghadge, P.N., P.R. Vairagar and K. Prasad, 2008. Physical Properties of Chick Pea Split (*Cicer arietinum* L.). *Agricultural Engineering International: The CIGR Ejournal*. Manuscript FP 07 039. Vol. X. January, 2008.

Gopalan, C., B.V. Romasastri and S.C. Balasubramanian, 1971. Nutritive value of Indian foods. National Institute of Nutrition, Hyderabad, India, PP: 204(reprinted).

Gopalan, C., B.V.R. Shastri and S.C. Balasubramanian, 1985. Nutritive Value of Indian Foods, National Institute of Nutrition (NIN), Indian Council of Medical Research, Hyderabad, India.

Hassan, H.A. and P.L. Bureng, 1996. Annual Report of Agricultural Research Corporation (ARC) in Sudan.

Hooda, S. and S. Jood, 2005. Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour. *Food Chem.*,

Hossney, R.C. and D.E. Rogeres, 1993. The formation and Properties of wheat flour doughs. In: *Dough rheology and baked product texture*. Work shop, TNO. Wageningen, Netherlands. 981

Ihekoronye, A.I. and P.O. Ngoddy, 1985. *Integrated Food and Technology for the Tropics*, Macmillan Publisher, London.

Indrani, D., P. Prabhasankar, J. Rajiv and G. Venkateswara Rao, 2007. Influences of whey protein concentrate on the rheological characteristics of dough, microstructure and quality of unleavened flat bread (parotta). *Food Res. Int.*, 40: 1254-1260.

Kachroo, P., 1970. *Pulse Crops of India*. ICAR, New Delhi.

Kent-Jones, D.W. and A.J. Amose, 1967. *Modern Cereal Chemistry*. 4th Edn., Northern Pub. Co. Ltd. Liverpool.

Lasztity, R. and L. Lasztity, 1990. Phytic acid in cereal technology. In: *Advanced in Cereal Science and Technology*. Published by the American Association of Cereal Chemists, St. Paul, Minnesota, USA, 10: 5.

- Lin, M.J.Y., E.S. Humbert and F.W. Sosulski, 1974. Certain functional properties of sunflower meal products. *J. Food Sci.*, 39: 363-370.
- Mailhot, W.C. and J.C. Patton, 1988. Criteria of flour quality In: *Wheat Chemistry and Technology*. Pomeranze, Y., (Ed.), Am. Assoc. Cereal Chem., St. Poul, MN.
- Mead, B. and R.W. Gurnow, 1983. *Statistical Methods in Agricultural Experimental Biology*. Chapman and Hall, London. New York.
- Mohammed, E.A., 2000. Evaluation of four local wheat cultivars with special emphasis on protein fractions. M.Sc. Thesis, University of Khartoum, Sudan.
- Mohammed, M.A., 2002. Production of cereal-based infant food from local raw materials. M.Sc. Thesis, University of Khartoum.
- Mustafa, A.I, M.S. Alwessali, O.M. SI-Busha and R.H. AIAmia, 1986. Utilization of cowpea flour and protein isolate in bakery products. *Cereal Food World*, 31: 756-759.
- Pratima, A. and M.C. Yadava, 2000. Effect of incorporation of liquid dairy by-products on chemical characteristics of soy-fortified biscuits. *J. Food Sci. Tech.*, 37(2): 158-161.
- Pyler, E.J., 1973. *Baking Science and Technology*, Tow Volumes. Sieble Publishing Company. Chicago, ILL.
- Price, N., I.G. Butler and S.V. Soloyo, 1978. Evaluation of the vanillin reaction as an assay for tannin in sorghum grain. *J. Agric. Food Chem.*, 26(5): 10-11.
- Quinn, M.R. and L.R. Beuchart, 1975. Functional property changes resulting from fungal fermentation of peanut flour. *J. Food Sci.*, 40: 475-480.
- Rao, P.U. and Y.G. Deothale, 1982. Tannin contents of cooking and germination. *Agric. Food Chem.*, 26: 316-319.
- Schruben, L.W., 1979. Principal of wheat protein pricing. In: *Wheat Protein Conference; Agric. Res. Manual ARMG, Sci and Ed. Admin. U.S.D.A* Singh, U., R.C. Jain, R.J. Jambunathan and P.G. Faris, 1984. Nutritive value of vegetable pigeon pea, mineral trace elements. *J. Food Sci.*, 49: 645.
- Singh, U., 1988. Anti-nutritional factors of chickpea and pigeon pea and their removal by processing. *Plant Food Hum. Nutr.*, 38: 251-261.
- Sulieman, A.E., Y. Osman and H. Yousif, 2003. Nutrition aspects of cow pea (*Vigna unguiculata*) U. K.J. *Agric. Sci.*, 11(3): 360-368.
- Vastala, C.N. and P. Haridis Rao, 1991. Studies on invert syrup for use in biscuit. *Food Sci.*, 28: 149-152. Wang, J.C. and J.E. Kinsella, 1976. Functional properties of noval proteins, Alfalfa leaf proteins. *J. Food Sci.*, 41: 286-290.
- Wheeler, E. and R.E. Ferrel, 1971. Phytic acid determination in wheat. *J. Cereal Chem.*, 48: 312-320.