Middle East Journal of Applied Sciences
ISSN 2077-4613

Volume : 06 | Issue :04 | Oct.-Dec.| 2016
Pages: 1160-1168

Utilization of amaranth meal in spaghetti preparation

[1]Abd El-Salam, Amira M., H.H. Hafez[1] and A.M.A. Sharoba[2]

[1]Food Technology Research Institute, Agricultural Research Center, Giza, Egypt.
[2]Food Sci. Dept., Faculty of Agric., Banha Univ., Moshtohor, Egypt.

Received: 10 Oct. 2016 /Accepted: 10 Dec. 2016 / Publication date: 31 Dec. 2016

ABSTRACT

Amaranth plant grows rapidly, with a high tolerance to arid conditions and poor soils. So, a trial was made to use mixture of amaranth meal with wheat flour in producing spaghetti. The quality attributes of spaghetti produced from wheat flour only or substituted by different levels (10-50%) of whole amaranth meal were studied. The quality characteristics of the spaghetti produced from different blends was compared to that of spaghetti produced from wheat flour as control. Chemical composition, minerals content and amino acids composition for raw materials and the product were determined. Rheological properties of doughs, cooking properties and sensory evaluation of all spaghetti samples were studied. The results indicated that protein, fat, ash, fibers, iron, zinc, magnesium and calcium contents of spaghetti samples significantly increased with increasing amaranth substitution. The amaranth meal substitution level of 50% increased water absorption of the dough from 61 to 71.3 %, dough development time from 2.20 to 5.20 min. and dough stability time from 5.00 to 8.30 min. While all amaranth substitution levels decreased dough weakening from 69 to 54 BU. Data for sensory evaluation indicated that adding of amaranth up to 30% was acceptable. The weight and volume increased by increasing amaranth meal. Meanwhile, cooking loss was slightly increased by increasing amaranth meal.

Keywords: Amaranth, wheat flour, spaghetti, rheological properties.

Introduction

Amaranth has been rediscovered as a promising food crop mainly due to its resistance to heat, drought, diseases and pests, and the high nutritional value of both seeds and leaves. Nutritionally, based on essential amino acid composition, amaranth grain has been assigned an exceptionally high chemical score of 73 in the recommended FAO/WHO scoring patterns. In fact, when amaranth grain is processed under conditions which do not damage the availability of essential amino acids, its protein quality is very closed to that of casein ((Bavec and Bavec 2006).

Amaranth (*Amaranthus cruentus*) which is ancient Central and South American crop, is currently cultivated in regions such as Mexico, Central and South America, Africa, India, and part of China (Valencia-Chamorro *et al.,* 2004). They are constantly studied by food scientists due to their high nutritional value, mainly as a result of their protein content (Schoenlechner *et al.,* 2008) and levels of essential amino acids (Valencia-Chamorro *et al.,* 2004).

Amaranth have excellent nutritional value because of its high content of essential micronutrients such as b-carotene, iron, calcium, vitamin C and folic acid. The amaranth grain is an excellent source of high quality protein and lipids and minerals as calcium, potassium, phosphorus, as well as dietary fiber, than cereal grains (Gorinstein *et al.,* 2002 and Berganza *et al.,* 2003)

Amaranth Grain is rich in proteins, lipids, energy and fiber than other cereal grains (Muyonga *et al*., 2008).

Amaranth grain has more protein than corn, and the protein is of an unusually high quality. It is high in the amino acid lysine, which is the limiting amino acid in cereals. The protein is also relatively rich in the sulfur containing amino acids, which are normally limiting in the pulse crops (e.g. dry beans). The "protein complement" of amaranth grain is very near to the levels recommended by FAO/WHO. It has a protein score of 67 to 87. Protein scores are determined by taking the ratio of the essential amino acids to the level for those amino acids recommended by FAO/WHO, and multiplying by 100. In comparison wheat, soybeans, rice and maize with protein contents of 14, 37, 7 and 9% respectively

Corresponding Author: Abd El-Salam, Amira M., Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. E-mail: amiraomar127@yahoo.com

recorded 47, 68-89, 69 and 35 protein scores, respectively. Although amaranth is theoretically closed to the ideal, combining it with another grains increases the quality to be closed to FAO/WHO standards. (Kelly, *et al*., 2008).

The amaranth-based products are a valuable source of nutrients and minerals. In addition, the amino acid profile of amaranth makes it an attractive source of protein. If consumed with other cereals, it is a balanced source of proteins; therefore, amaranth meal is often used in mixtures with maize or wheat (Alvarez-Jubete *et al*., 2010).

Pasta is an inexpensive food usually made from wheat, which is consumed in most countries worldwide. It is, however, rather low in protein (<15%protein) and is relatively deficient in lysine, as an important essential amino acid. This is especially important for efforts to feed the poor people using pasta as the primary source of calories and protein. Pasta and bread made from low-protein grains make up a sizeable portion of diets among the undernourished in some countries in Africa and Asia. Even in the U.S., diets deficient in protein occur among the poor who sometimes depend on low-cost bread and pastas for nutrition. (Shogren *et al.,* 2006).

Rayas-duarte *et al*. (1996) substitute durum wheat flour with amaranth meal at 5, 15, 25, and 30% to produce pasta. The samples were analyzed for cooked weight, cooking loss, lysine content, and sensory attributes. They found that the cooking loss ranged from 7.2 to 8.0%. It significantly higher than that of the controls but still at acceptable levels. The lysine content increased as the substitution level of amaranth increased. Sensory evaluation showed that changes in texture and flavor were detected at 30% and 25% of amaranth. The results showed that pasta can be produced with higher levels of lysine than commercial pasta made of 100 % durum wheat flour and also with acceptable cooking quality and sensory attributes.

The present work aims to utilize of amaranth meal which has high protein and minerals contents with wheat flour to prepare high nutritive value spaghetti.

Materials and Methods

Materials:

Wheat flour (72 %extraction) was obtained from South Giza Company, Egypt.
Amaranth light seeds (*Amaranth hypochondriacus* L.) were obtained from Horticulture Dept., Fac. Agric., Suez Canal Univ., Ismailia, Egypt.
Salt was obtained from local market of Giza, Egypt.
Pectin was obtained from Egyptian scientific company- El-Dokki Giza.

Methods

Preparation of different blends:

Whole meal of amaranth seeds was produced by milling clean seeds using Senior Quadrumat roller mill (Brabender, Germany). The milled seeds were used in the preparation of spaghetti, after passing through 60 mesh. Different blends were prepared as presented in Table (1).

Table 1: The formula of spaghetti samples

Ingredients	Blends composition					
	W.F. (Control)	A.M 10%	A.M 20%	A.M 30%	A.M 40%	A.M 50%
Wheat flour 72% ext.	100	90	80	70	60	50
Whole-meal of amaranth	0	10	20	30	40	50
Salt	1	1	1	1	1	1
Pectin	1	1	1	1	1	1

W.F: Wheat flour A.M.: Amaranth meal

Determination of rheological properties:

Rheological properties of the dough's were determined using farinograph (type Brabender farinograph–Germany) and extensograph (type Brabender extensograph- Germany) according to A.A.C.C. (2005).

Spaghetti processing:

Spaghetti was prepared in laboratory molder (Demaco, De francis machine corporation Germany) according to the method described by Dexter *et al.* (1990) with some modifications. One kilogram of each of flour blends of the of raw materials was mixed with the required amount of water ranged from 33% to 36% in the Hobart mixer (model C- 100, Germany). After the complete addition of water, mixing was continued for 8 min. The premixed dough was placed in the vacuum mixer of the Demaco molder and extended at a rate of 21 rpm., at 25 C^{o} temperature. An extension tube was added to ensure uniform hydration of the pasta dough prior to extrusion. The pasta was dried for 24 hr at 6o C^{o}.

Chemical analysis

Determination of moisture, fat, ash, crude fiber, crude protein and essential minerals were determined according to A.O.A.C. (2005).
Available carbohydrates = 100-(protein % +fat %+ash%+fiber %)
Total calories was calculated according to FAO/WHO (1973) as follows:
E = 4X (Carbohydrate %+ protein %) + 9X (fat %)
Where: E = Energy as kcal per 100gm.

Cooking quality of spaghetti:

Physical characteristics of cooked spaghetti:

Weight increase % and volume increase % of spaghetti were determined according to the method described by Dexter *et al.* (1990) by cooking 25 g of each sample in one litter of boiling water for 5 min., the samples were washed and allowed to drain for 2 min.
Weight increase% = [(Weight of cooked sample- weight of uncooked sample) / (weight of uncooked sample)] X100.
Volume increase % = [(volume of cooked sample-volume of uncooked sample) / (volume of uncooked sample)] X100.

Determination of cooking loss% :

Total soluble solids of cooking liquid were determined as cooking loss% according to the method of Walash and Cilles (1971). The residue weight was calculated as a percentage based on the uncooked product weight as follows:
Cooking loss% = (weight of residues in cooking water/weight of uncooked sample) X100.

Sensory evaluation of spaghetti:

The quality of cooked spaghetti was evaluated for appearance, color, stickiness, tenderness, taste and flavor according to the method of Aravind *et al.* (2012) by ten panelists from the staff of Food Technology Research Institute, Agriculture Research Center, Giza, Egypt as following: appearance (20), color (20), odor (20), tenderness (20), stickiness (20) and total score (100).

Determination of amino acids:
Amino acid composition was measured in duplicate according to the methods of Official Methods (A.O.A.C 2005).

Statistical analysis:

The obtained results of chemical composition, physical properties and sensory evaluation were statistically analyzed by the least significant difference value (L. S. D.) at 0.05 levels probability by Snedecor and Cochran (1980).

Results and Discussion

Chemical composition of raw materials:

Data in Table (2) showed the chemical constituents of the raw materials and the results indicated that wheat flour and amaranth meal contained 12.2 and 17.40% protein, 0.80 and 4.50 % fat, 0.50 and 3.14% ash, 0.71 and 4.03 % fibers, and 85.79 and 70.93 available carbohydrates. It could be noticed that the amaranth meal have significantly higher content of protein, fat, ash and fibres compared with wheat flour. These results are in agreement with those reported by Písaříková *et al.,* (2005) who analyzed five species of grain amaranth in Nigeria for chemical composition and they found that the protein content ranged from 14.25 to 17.89%, fat content ranged from 4.85 to 8.68%, fibers content ranged from 1.89 to 4.04% and ash content ranged from 3.14 to 4.94%

Table 2: Chemical composition of wheat flour (72 %) and amaranth meal (100%) (on dry weight basis).

Sample	Protein (%)	Fat (%)	Ash (%)	Crude fibers (%)	Available carbohydrate (%)
Wheat flour 72%	12.20^{b}	0.80^{b}	0.50^{b}	0.71^{b}	85.79 ^{a}
Amaranth meal 100%	17.40^{a}	4.50^{a}	3.14^{a}	4.03^{a}	70.93 ^{b}
LSD $_{0.05}$	1.6	1.14	1.14	1.13	1.6

Each value in the same column followed by the same letter or letters is not significantly different at level of 0.05

Minerals contents of raw materials.

Data in Table (3) represent the minerals contents of the raw materials. From the obtained data, it could be observed that amaranth meal was superior in calcium, magnesium, iron and zinc compared with wheat flour (72%).These results are in agreement with those reported by Palombini *et al.*, (2013) who mentioned that amaranth had high content of calcium, magnesium and iron which were found to be 283.14, 425.21 and 29.35 mg/100g, respectively therefore it could be concluded that fortification of wheat flour with amaranth meal can produce macaroni with high levels of minerals (Kachiguma *et al.,* 2015).

Table 3: Minerals content of raw materials (mg/100gDM)

Sample	Ca	Mg	Fe	Zn
Wheat flour 72%	22.32^{b}	116.0^{b}	1.13^{b}	0.91^{b}
Amaranth 100%	174.61^{a}	239.4^{a}	9.98^{a}	3.81^{a}
LSD $_{0.05}$	1.2	1.6	0.23	1.13

Each value in the same column followed by the same letter or letters is not significantly different at level of 0.05

Amino acids content of raw materials:

Data in Table (4) indicated that amaranth meal contained all amino acids presented in wheat flour (essential and nonessential amino acid). Amaranth meal have higher percentages for lysine, cysteine, tyrosine, threonine, isoleucine and leucine compared with wheat flour (72 %). The cysteine contained sulfur which improved gluten net by inter in sulfur bond. So the addition of amaranth meal to wheat flour improve dough characteristics in wheat flour (Palombini *et al.*, 2013).

Farinograph parameters of wheat flour doughs blended with amaranth meal:

Data in Table (5) showed the effect of blending amaranth meal with hard wheat flour (72 % ext.) on the farinograph parameters, i.e. water absorption, arrival time, dough development time, dough stability and dough weakening. Water absorption of the control (wheat flour 72 ext.) showed a value of

61.0%. While wheat flour blended with different ratios of amaranth meal, (10, 20, 30, 40 and 50 %) showed a gradual increase in parallel with amaranth meal increase, this may be due to the high protein and fiber contents in amaranth meal. Arrival time showed a time in min ranged between 1.50- 3.20 for amaranth doughs. Dough development time of blends with amaranth meal at the ratios of 10, 20, 30, 40 and 50 % resulted in 2.60, 3.20, 3.90, 4.80 and 5.20 min., respectively but it was 2.20 min. for wheat flour (72 % ext.).Dough stability recorded its maximum value (8.30 min.) when the blend contained 50% amaranth meal and 50 % wheat flour extraction. From the above mentioned data, it could be concluded that, the replacement of amaranth meal at different ratios improved the gluten network and farinograph parameters of the wheat flour dough. A gradual decrease in degree of dough weakening were observed in parallel with amaranth meal increase.

Sharoba *et al*. (2009) reported that**,** the replacement of amaranth meal at different ratios improved the gluten network and farinograph parameters of the wheat flour dough.

Table 4: Amino acids percentages of amaranth meal and wheat flour (%of protein).

Amino acids	**Amaranth meal**	**Wheat flour 72%**
Essential amino acids %		
Lysine	5.30	1.20
Cysteine	3.30	1.67
Methionine_	3.50	4.50
Phenylalanine	4.16	4.50
Tyrosine	4.50	3.50
Valine	4.50	5.66
Threonine	4.58	4.18
Isoleucine	4.50	4.18
Leucine	6.26	5.95
Non-essential amino acids%		
Arginine	9.08	8.50
Histidine	2.58	5.10
Aspartic	9.18	8.50
Serine	6.94	7.00
Glutamic	14.20	13.80
Proline	5.40	9.00
Glycine	6.86	6.70
Alanine	3.16	4.30
Tryptophan	2.00	1.76
Total essential % amino acids	40.60	35.34
Total non-essential amino acids %	59.40	64.66

Table 5: Farinograph parameters of doughs made from 72% ext. wheat flour (WF) substituted by different levels of Amaranth meal.

Sample	**Farinoghaph parameters**				
	W.A (%)	**A.T. (min)**	**Dev.T (min)**	**Sta.T (min)**	**D.W (B.U)**
W.F.(control)	61.00	1.20	2.20	5.00	69.00
A.M. 10%	63.20	1.50	2.60	6.30	68.00
A.M. 20%	65.30	1.70	3.20	7.00	63.20
A.M. 30%	67.00	1.80	3.90	7.30	59.9
A.M. 40%	69.00	2.6	4.80	8.00	56.00
A.M. 50%	71.30	3.20	5.20	8.30	54.00

W.F. = Wheat flour A.M. = Amaranths meal W.A: Water absorption. A.T.: Arrival time(min)
Dev.T: Development time. Sta T.: Stability time. D.W : Degree of weakening. (B.U):Barabender unit.

Extensograph parameters of wheat flour doughs blended with amaranth meal:

Data in Table (6) showed the effect of blending amaranth meal at ratios of 10, 20, 30, 40 and 50 % with wheat flour 72% ext. on the extensograph parameters, i.e. Resistance to extension (R), Extensibility (E) and the ratio between them and also the energy. The results showed that the resistance to extension was 750 B.U. for the control (wheat flour 72% ext.), while it decreased with increasing the levels of amaranth meal in prepared blends. extensibility (E) showed a value of 160 mm for the control wheat flour (72% ext.). Blending with amaranth meal showed a gradual decrease in extensibility (E) values as amaranth meal increase. The lowest extensibility value was recorded for the blend containing 50% amaranth meal. The ratio between resistances to extension and extensibility reflects the effect of blends on the elasticity of the produced dough. Concerning the energy, the control showed the highest value while it decreased for other treatments. Sharoba *et al.* (2009) reported that, the addition of amaranth meal had a little effect on extensograph parameters almost like the control.

Table 6: Extinsograph parameters of doughs made from 72% ext. wheat flour (WF) substituted by different levels of Amaranth meal.

Samples	Extinsograph			
	Res.to Ext.(B.U)	Extensibility (mm)	P.N. (R / E)	Energy(cm^2)
W.F.(control)	750.0	160.0	4.69	140.0
A.M. 10%	735.0	157.2	4.68	138.2
A.M. 20%	729.0	153.0	4.76	135.0
A.M. 30%	710.0	148.0	4.80	132.4
A.M.40%	680.0	144.0	4.72	128.5
A.M. 50%	650.0	135.0	4.81	125.0

W.F.: Wheat flour A.M.: Amaranths meal Res.to Ext. (B.U): Resistance to extension (B.U) P.N. :Proportional number (R / E)

Chemical composition of spaghetti:

Data in Table (7), showed that, all samples of spaghetti which containing amaranth meal had the higher value of protein, fat, ash and crude fiber and lower value of available carbohydrate compared with the control (spaghetti without amaranth). All samples of spaghetti which containing amaranth meal had protein content ranged from 12.06-14.43 %, 1.37-4.02 % fat, 0.66-1.51 % ash, 1.02-2.23 % fiber and 84.89-77.81%, available carbohydrate while the control spaghetti had protein value of 11.55%, 0.66 % for fat, 0.45% for ash, 0.62% for crude fiber and 86.72% for available carbohydrate. It could be also noticed that substituting wheat flour with amaranth caused an increase in protein by 4.42-24.94 % in spaghetti compared with the control. Also, amaranth caused an increase in fat ash, fiber and calories, These results are in agreement with (Rayas-Duarte *et al.* 1996 and Pattacini *et al.,* 2005).

Table 7: Chemical composition of spaghetti samples (on dry weight basis):

Spaghetti sample	Chemical componant					
	Protein (%)	Fat (%)	Ash (%)	Fibres (%)	Available Carbohydrate (%)	Calories kcal/100g
W.F. (Control)	11.55^{d}	0.66^{d}	0.45^{a}	0.62^{c}	86.72^{a}	399.02^{d}
A.M.10%	12.06^{cd}	1.37^{d}	0.66^{a}	1.02^{bc}	84.89^{b}	400.13^{cd}
A.M.20%	12.72^{bcd}	2.05^{cd}	0.87^{a}	1.33^{b}	83.03^{bc}	401.45^{c}
A.M.30%	13.32^{abc}	2.80^{bc}	1.08^{a}	1.62^{ab}	81.18^{c}	403.20^{b}
A.M.40%	13.91^{a}	3.51^{ab}	1.31^{a}	1.93^{ab}	79.34^{d}	404.59^{ab}
A.M.50%	14.43^{a}	4.02^{a}	1.51^{a}	2.23^{a}	77.81^{f}	405.14^{a}
LSD0.05	1.60	1.13	1.15	0.67	1.55	1.60

Each value in the same column followed by the same letter or letters is not significantly different at level of 0.05
W.F.: Wheat flour A.M.: Amaranths meal

Minerals composition of spaghetti:

The results presented in Table (8), showed that all samples of spaghetti containing amaranth levels had the higher values in minerals content (i.e., calcium, Iron, zinc and magnesium) compared with the control (spaghetti without amaranth flour). This increment as a result of high minerals content of amaranth meal compared with wheat flour. Hence, spaghetti samples containing amaranth meal favorable because of their high content of important minerals which depend upon the amaranth meal as reported by Palombini et al. (2017).

Table 8: Minerals composition of spaghetti (mg/100gDM).

Samples spaghetti	Minerals			
	Ca	Fe	Zn	Mg
W.F.(control)	20.31^{f}	1.02^{f}	0.91^{f}	115.45^{f}
A.M. 10%	36.31^{e}	2.06^{e}	1.31^{e}	127.95^{e}
A.M. 20%	51.32^{d}	2.81^{d}	1.63^{d}	140.55^{d}
A.M. 30%	66.92^{c}	3.61^{c}	1.94^{c}	153.15^{c}
A.M. 40%	81.90^{b}	4.33^{b}	2.29^{b}	165.55^{b}
A.M. 50%	97.3^{a}	5.12^{a}	2.40^{a}	178.05^{a}
LSD 0.05	0.31	0.24	0.01	1.60

Each value in the same column followed by the same letter or letters is not significantly different at level of 0.05.
W.F.: Wheat flour A.M. : Amaranths meal

Cooking quality of spaghetti:

The cooking quality of spaghetti prepared from the differant levels of amaranth (10-50%) was detrmined Data in Table (9) showed that the weight incerase % and volume incerase % of spaghetti made from amaranth were higher than control.This may be due to the higher swelling power of spasghetti made from amaranth compared with the spaghetti made from hard wheat flour 72% ext, as a result of high fiberes and protein contents which absorb more water than starch. Spaghetti with amaranth showed the higher cooking loss, this may be due to the increase in fiber content in spaghetti which contained amaranth meal and the ability of amaranth to form gel with water.

Table 9: Cooking quality of spaghetti

Samples spaghetti	Cooking quality		
	Volume increase %	Weight increase %	Cooking loss %
W.F.(control)	230^{f}	190^{f}	4.50^{f}
AM. 10%.	242^{e}	199^{e}	5.30^{e}
AM. 20%.	251^{d}	210^{d}	6.00^{d}
AM. 30%.	271^{c}	229^{c}	7.00^{c}
AM. 40%.	289^{b}	240^{b}	8.10^{b}
AM. 50%.	295^{a}	245^{a}	9.00^{a}
LSD 0.05	1.6	1.6	0.16

Each value in the same column followed by the same letter or letters is not significantly different at level of 0.05
W.F. : Wheat flour A.M. : Amaranths meal

Sensory evaluation of spaghetti:

The sensory characteristics, i.e. appearance, color, odor, tenderness, stickiness total score for spaghetti produced from wheat flour 72% extraction containing different ratios of whole-meal of amaranth (10, 20, 30, 40 and 50 %) were evaluated by ten panelists. The tested spaghetti samples proved to be inferior in average values of organoleptic properties as compared with control samples. It was also proved that the high level of whole-meal of amaranth substitution had the lower values scored for the resulting spaghetti with insignificant (P>0.05) quality reduction was observed at 30 % whole-meal of amaranth substitution level for all sensory attribute except tenderness and total score and with

significant (P<0.05) reduction at higher levels. From these results it could be concluded that whole-meal of amaranth could be added to wheat flour to produce acceptable spaghetti to some extent and the level of addition can be reached up to 30% of amaranth meal as an economical level with the acceptable properties (total score 85%).

Table 10: Sensory evaluation of spaghetti sampls

Spaghetti samples	Sensory properties					
	Appearance (20)	Color (20)	Tenderness (20)	Odor (20)	Stickiness (20)	Total score (100)
W.F.(control)	19.0[a]	19.0[a]	18.5[a]	19.0[a]	19.0[a]	94.5[a]
A.M. 10%	18.0[a]	18.0[a]	18.5[a]	18.0[a]	18.5[a]	91.0[b]
A.M. 20%	18.0[a]	18.0[a]	18.5[a]	17.0[b]	17.0[b]	88.5[b]
A.M. 30%	17.0[b]	17.0[b]	16.0[b]	16.0[bc]	17.0[b]	83.0[c]
A.M. 40%	14.5[c]	15.0[c]	16.5[b]	15.0[c d]	15.0[c]	76.0[d]
A.M. 50%	13.0[c]	15.0[c]	16.0[b]	14.0[d]	14.0[c]	72.0[e]
LSD 0.05	1.60	1.27	1.27	1.60	1.13	2.51

Each value in the same column followed by the same letter or letters is not significantly different at level of 0.05
W.F.: Wheat flour A.M. : Amaranths meal

Conclusion

From the obtained data, the amaranth meal had higher contents of protein, fat, ash, crude fibers and essential amino acids. The blends dough from wheat flour and amaranth meal had good characteristic in rheological properties. The pasta obtained from amaranth meal showed some detriment of the technological and sensory quality. So, a maximum substitution level of 30% w/w was recommended. This is an equilibrium point between an acceptable pasta quality and the improved nutritional and functional properties.

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