ISSN 1110-0419

Annals Of Agric. Sci., Moshtohor,
Vol. 47(2): Fo. 105-120, (2009).

QUALITY ATTRIBUTES OF SAUSAGE SUBSTITUTED BY DIFFERENT LEVELS OF WHOLE AMARANTH MEAL
BY

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ABSTRACT

Production of comminuted meat products such as sausage is progressively increasing in Egypt. Amaranth plant grows rapidly, with a high tolerance to arid conditions and poor soils. So, a trial was made to use whole amaranth meal in producing sausage. The quality attributes of sausage produced from beef meat as main ingredients or substituted by different levels of whole amaranth meal were studied. Chemical composition, freshness tests, physicochemical evaluation, microbiological examinations were determined. The energy values for produced sausage were estimated. Texture properties were measured using the food texture Instron Universal Testing Machine (Model 4302) (Penetration test (PT) and Compression test (CT). Sensory evaluation for produced sausage was carried out and the data were statistically analyzed. Obtained results showed that using of whole amaranth meal increased total carbohydrate and ash but the other chemical composition were decreased in sausage. While there are changing in chemical composition, the nutritional values for all produced sausage were nearly the same. The TVN and TBA were increased with increasing storage time. The increase in TVN and TBA of substituted samples were lesser than control sample. In the same time TVN and TBA for all produce sausage samples were within the Egyptian standard requirements. Whole amaranth meal increased cooking yield and decreased frying and cooking loss. The microbiological quality of all produced sausage was within the Egyptian standard requirements. The sausage substituted with 5, 10 % of whole amaranth meal were accepted nearly as control sausage. Texture properties of sausage are affected by substitute levels of whole amaranth meal and storage period. The results indicated that whole amaranth meal can be utilized in making sausage.

Key words: Sausage. Texture properties. Maximum force. Hardness. Softening. Chemical composition. Freshness tests. Physicochemical properties. Microbiological quality. Sensory characteristics.

INTRODUCTION

Amaranth was a staple food of the pre-Columbian Aztecs, which first found its way to the American from China (Chillo *et al*., 2008). The genus *Amaranthus* L., which originated in the Americas, consists of 60–70 species, including 3 cultivated grain amaranth species (*A. caudatus, A. cruentus*, and *A. hypochondriacus*). The amaranths grain are ancient crops with increasing prospects as potential food and feed resources because of their high grain protein and starch quality and high-nitrogen, highly digestible vegetative tissues (Cai *et al.,* 1998 a,b). Amaranthus species are also cultivated in many parts of the world as ornamentals and as leafy vegetables.

Interest in amaranth grain has increased in recent years because of its high nutriational value as well as some agricultural advantages such as relative high grain yield, resistance to drought and short production time (Mendoza and Bressani, 1987). Amaranth proteins contain acceptable levels of essential amino acids, particularly lysine, tryptophan and methionine, which are found in low concentrations in cereals and legumenous grains of common usage (Mendoza and Bressani, 1987; Teutonico and Knorr, 1985). The amaranth grain is nearly spherical, about 1 mm in diameter, with remarkable nutritional properties. It contains approximately 63% starch, with waxy characteristics (Yanez *et al.,* 1986) and 15% proteins, with significant content of sulphur amino acids and lysine (Lehmann, 1996; Saunders and Becker, 1984; Teutonico and Knorr, 1985). Although it is a dicotyledonous plant, some authors consider it a pseudocereal (Breene, 1991) as a consequence of its properties and characteristics.

Although animal proteins are widely used in food formulation because of their high nutritional value and their versatile functional performance, it is desirable to find alternative protein sources, more economic and with high nutritional quality and bioavailability. Several plant proteins have been studied to achieve this goal, including storage proteins from soy, pea and sunflower (Gonzalez-Perez and Vereijken, 2007; Rangel *et al.,* 2003; Tsumura *et al.*, 2005). More recently the interest has been focused on ancestral crops, such as amaranth, which seeds contain proteins with a well-balanced composition in essential amino acids and important content of sulfur-containing amino acids (Bressani, 1989), which added to their well known agronomic advantages (Lehmann, 1996).

As a whole grain, amaranth is being increasingly used in breads and cookies (Sanchez-Marroquin *et al.*, 1985) as well as pasta and breakfast cereals (Lehmann, 1992).

In meat products, several ingredients and source of proteins (soy, maize, whey protein, egg white, wheat and cotton seed) and source of carbohydrates (starch, pectin, cellulose gum and maltodextrins) have been studied. The obtained results were satisfactory, which improve many properties such as cooking yield, enhance water holding capacity, reduce formulation cost and modify texture (Lytras *et al.*, 2002; Yilmaz *et al.*, 2002; Zanardi *et al.*, 2002; Modi *et al.*, 2003; Fista *et al.*, 2004; Madkour *et al.*, 2004 and Pouttu and Puolanne 2004).

Recently, Egypt started trials and experiments for cultivation amaranth. Therefore, owing to all these advantages, using such as a plant seeds may be substantial idea in testing it in the field of meat products to improve product quality and to save the raw material costs. Moreover to publish the benefits of amaranth. So, a trial to utilize the whole amaranth meal as meat substitute in different levels in sausage making. Beside, the quality attributes of sausage from beef meat substituted by different levels of whole amaranth were studied.

MATERIALS AND METHODS

Materials:

Amaranth seeds:

Amaranth light seeds (*Amaranthus hypochondriacus L*) were obtained from Horticulture Dept., Fac. of Agric., Suez Canal Univ., Ismailia, Egypt, (with chemical composition: moisture 10.11%, protein 17.24%, fat 7.63%, ash 3.29%, crude fiber 4.38% and available carbohydrates 67.46%, on dry weight basis).

Sausage ingredients:

Fresh beef meat (with chemical composition: moisture 74.69%, protein 84.87%, fat 10.55%, ash 3.97% and available carbohydrates 0.61% on dry weight basis), and mutton fat was purchased from butcher shop in Kaha City, Qalyoubia Governorate and immediately transported in ice box to the laboratory. Other ingredients such as salt, garlic, spices (black pepper, cardamom, clove, cubeb, fennel, coriander and laurel), dried skim milk, and starch were obtained from the local market in Toukh City, Qalyoubia Governorate. Sodium nitrate, glucose, ascorbic acid and sodium pyrophosphate were obtained from El-Nasr Co., Cairo, Egypt. Artificial casing was obtained from local market in Cairo city.

Methods:

Preparation of whole-meal of amaranth seeds:

Whole-meal of amaranthus seeds was produced by milling clean seeds using Senior Quadrumat roller mill (Brabender, Germany). The milled was used in the preparation of meat products.

Preparation sausage (control):

Sausage was prepared by the common method according to the following table:

The formula of sausage prepared in laboratory:

Components	%	Spices mixture	%
Beef meat	70.60	Fennel	60.76
Mutton fat	14.00	Coriander	27.68
Ice water	7.00		
Starch	4.65	Cubeb	3.19
Sodium pyrophosphate	0.30		
Salt	2.00	Black pepper	3.19
Garlic	0.24		
Dried skim milk	0.40	Clove	3.19
Glucose	0.10		
Ascorbic acid	0.04	Laurel	1.99
Sodium nitrate	0.01		
Spices mixture	0.66	Cardamom	1.59

Meat and fat were ground, and then mixed in a bowl chopper with adding the salt. Ice was added in three stages to save the temperature of mixture, other additives and spices were added and finally the starch was added. The mixture was taken out of the bowl chopper and was filled into artificial casings of 20 $\pm$ 2 mm diameter. Beef sausage was put in plastic bag and stored at -18°C for 3 months.

Sausage preparation with adding whole amaranth meal:

Another four batch of sausage were prepared as same previous method with adding whole amaranth meal as 5, 10, 15 and 20% replacement as partial part from meat. The sausage was stored at -18°C for 3 months.

Analytical methods:

Chemical analysis:

Moisture content, crude protein (total N x 6.25), fat and ash contents were determined according to A.O.A.C. (2000). Total carbohydrates content was calculated by differences.

Energy values:

Total calorie estimates (kcal) for uncooked sausage were calculated on the basis of a 100 g sample using Atwater values for fat (9 $kcalg^{-1}$), protein (4.02 $kcalg^{-1}$) and carbohydrate (3.87 $kcalg^{-1}$) (Mansour and Khalil, 1997).

Energy values = (Carbohydrate x 3.87) + (protein x 4.02) + (fat contents x 9)

Freshness tests:

Total volatile nitrogen (T.V.N.) was measured according to the method of the Harold *et al.* (1987) and the results were calculated as mgTVN/100g. Thiobarbituric acid value (T.B.A.) was colorimeterically determined as described by Harold *et al.* (1987).

Physicochemical properties:

The pH values were measured using a pH meter model Consort P107 according to Defreitas *et al.* (1997). Water holding capacity (W.H.C.) and plasticity were measured by filter press method of Soloviev (1966).

Microbiological examination:

Total viable bacterial count (TVBC), Psychrophilic bacteria, yeasts and moulds (Y&M), lactic acid bacteria and coliform group were examined according to the methodology of the American Puplic Health Association (1992) and Oxoid (1990).

Cooking method:

The cooking methods to determine the softening and cooking properties were done according to Tan *et al.* (2007). Sausage in polyethylene bags was cooked in water bath at 90ºC. until the central temperature of the sausage reached and held at 72 ºC. (measured and control by thermocouple Digi-Sense Model 92800-15, Col-Parmer Company) for 8 min, and cold at room temperature then the texture properties were measured.

Frying method:

Sausage was fried according to Wills and Kabirullah (1981). Samples were fried in soybean oil at 160°C. for 5 min.

Frying and cooking loss:

Frying and cooking loss of samples was calculated as percentage of weight change from the raw to fried or cooked state.

Mechanical properties measurements:

All mechanical properties were made using the Instron Universal Testing Machine (Model 4302) equipped with: 5-mm diameter tip probe for penetration test and flat plate probe for compression (with 100 and 500N load cell) (in Food Development Center Kaha city) as described by Bourne (1982). All testing was performed at room temperature (25ºC). Mechanical properties were analysed by using central cores of 3 slices of each sample (1 cm high and 2.1 cm diameter) which were penetrated or compressed to 50% of their original height.

Penetration test (PT):

Each piece (1 cm high and 2.1 cm diameter) of tested sausage was placed in a hole of the bevelled ring. The pin penetrated with a constant speed of 5 $mm.min^{-1}$ into each piece of tested sausage.

Compression test (CT):

Samples were compressed in a one cycle compression test at a constant speed of 50 $mm.min^{-1}$, using a circular flat plate. Force – deformation curves were recorded and hardness was derived as indicators of textural properties. Each sample was used for only one measurement. At least 3 measurements were taken for each test condition.

Mechanical measurements analysis:

1- The force corresponding to the maximum compression is defined as the maximum force (F_{max}). The maximum puncture force (F_{max}) was measured in Newtons (N), as mentioned Thiagu *et al.*(1993).
2- Maximum deformation: the distance from beginning to distance at maximum force.
3- Hardness = Maximum force (N) / Maximum deformation (mm), as mentioned by Nourian *et al.* (2003 a,b).
4- Softening = {(1- (maximum force of cooked sample/ maximum force of raw sample)) x 100}, as mentioned by Chiavaro *et al.* (2006).

Sensory evaluation:

Sensory evaluation was carried out on sausage samples immediately after preparing, 1, 2 and 3 months of storage. Samples were frying and sliced then subjected to a 10 staff member trained on sensory evaluation to find out the sausage products that will be have more palatability by evaluating color, flavor, taste, hardness, juiciness and overall acceptability of these products according to Garcia *et al*. (2002) and Watts *et al*. (1989).

Statistical analysis

ANOVA was carried out on data of the sensory evaluation applying the function of two factors with replicates "Excel" Software of Microsoft Office 2003. L.S.D. analysis was adapted according to Gomez and Gomez (1984). Data are expressed as mean $\pm$ SE.

RESULTS AND DISCUSSION

Chemical composition of sausage made from beef meat substituted by different levels of whole amaranth meal:

The chemical composition of produced sausage is shown in Table (1). It could be noticed that moisture content of sausage samples was decreased by increasing either whole amaranth meal substitute ratio from 0 to 20 % or frozen storage time from 0 to 3 months. Moisture content decreased from

57.55 to54.79 for control sample at 0 month frozen storage and sample substituted with 20 % whole amaranth meal at 3 months frozen storage, respectively. Crude protein percentage of sausage samples has the same trend as moisture content of sausage samples. Crude protein was decreased from 15.61 to 14.51% by increasing whole amaranth meal substitute ratio from 0 to 20 % at 0 frozen storage time. This could be referred that whole amaranth meal contains more than fifty percent carbohydrate (Betschart *et al.*,1981; and Lehmann, 1996). Crude protein was decreased by increasing frozen storage time from 0 to 3 months. It decreased from 15.61 to 15.01 for control sample at 0 and 3 months frozen storage, respectively. This decrease in protein content may be due to protein hydrolysis by natural meat enzymes and bacterial enzymes that are produced as well as the loss of water soluble protein with separated drip. These results are similar to that obtained by Gibriel *et al.* (2007) and Madkour *et al.* (2000). Ether extract percentage of sausage samples has not the same trend as moisture content and crude protein of sausage samples. Ether extract was decreased from 18.49 to 17.01 % by increasing whole amaranth meal substitute ratio from 0 to 20 % at 0 month frozen storage time. This could be referred that meat contains higher ether extract % than whole amaranth meal (10.55 and 7.63%, respectively). Ether extract percentage was increased from 18.49 to 19.92 by increasing frozen storage time from 0 to 3 months for control sample. Regarding for ash, results indicated that sausage had high substitute of whole amaranth meal contained high percentage of ash. The percentage of ash for all sausage samples was increased gradually with increasing time of storage. The carbohydrates in sausage resulted from adding other meat ingredients plus whole amaranth meal. Carbohydrates was increased by increasing whole amaranth meal substitute ratio from 0 to 20 %. While, it was decreased with increasing frozen storage time from 0 to 3 months. Carbohydrates increased from 5.45 to 9.44 for control sample at 0 month storage and sample substituted with 20 % whole amaranth meal at 3 months storage, respectively. The previous result related to that whole amaranth meal contained more than fifty percent of carbohydrate. The changes of carbohydrates percentage related to other changes in other chemical components. Consumption 100g of sausage contains whole amaranth meal 0, 5, 10, 15, 20% cover acceptable part of daily require with acceptable balance related for meat and whole amaranth meal which contain good quality and quantity of amino acids. These results are in agreement with those reported by Nuzhat *et al.* (2002) Bahlol and Abd El-Aleem (2004) and Abd El-Aleem and Mohamed (2005) but they used substitute material other whole amaranth meal such as legumes, mung bean and soy bean.

Physico-chemical properties and cooking parameters of sausage made from beef meat substituted by different levels of whole amaranth meal.

Freshness test, physico-chemical properties and cooking parameters of sausage are presented in Table (2). The TVN amounted to 8.65 mg/100g in fresh beef sausage. Substituting sausage with whole amaranth meal at level from 5 to 20 % decreased the TVN till 6.92. The TVN increased gradually with increasing frozen storage time. This increase in substituting sausage was less than sausage control. The TBA test has been widely used to measure lipid oxidation in meat and meat products (Fernandez-Lopez *et al.,* 2006 and Aleson-Carbonell *et al,* 2005). The TBA values results took the same trend in TVN.

The lowest TBA was obtained in sausage contained 20% of whole amaranth meal, while the highest TBA values was obtained in control sausage at zero time. These differences could attribute the higher percent of fat which could speed up lipid oxidation. TBA increased for all sausage with increasing storage time. The increasing in TBA in sausage contained whole amaranth meal less than the increasing in TBA in control sausage. With respect to pH value, generally it could be noticed that increasing the storage period from 0 to 3 months was accompanied by increasing pH value.. Also the general trend for effect of increasing the substitution ratio by whole amaranth meal from 0 to 20 % was accompanied by increasing pH value. However the changes in TVN and TBA for all sausage products were under Egyptian standard (2005) for sausage products. The changes in pH related the activity of some organisms and which may be due to some protein break down with the formation of small amount of basic compounds such as ammonia. The increasing rate of TVN, TBA and pH in beef sausage during freezing for 3 months were accepted for human consumption.

One important attribute of sausage and other meat products is the ability to hold moisture and other juices in the product both before and after treatment. The Water holding capacity (WHC) is one of the most important properties, beside the eating quality, tenderness, juiciness, thawing drip and cooking loss of meat and meat products. The control sample showed highest WHC and plasticity compared with sausage contained whole amaranth meal at zero time. It could be noticed that, the WHC and plasticity of all sausage progressively decreased with increasing storage period. This might be explained on the basis of denaturation and or aggregation of protein during frozen storage. These results are in agreement with the results of Madkour *et al.* (2000) and Gibriel *et al.* (2007).

The Data presented in Table (2) shows that all sausage substituted with whole amaranth meal had higher cooking yield and lower total frying loss compared to the control sausage. As a general trend, cooking yield increased and frying loss decreased as whole amaranth meal substitute ratio increased. The lowest frying loss was obtained in sausage contained 20% of whole amaranth meal, while the highest frying loss was obtained in control sausage at zero time. Cooking loss results took the same trend in the results of frying loss within highest values.

Table (1): Chemical composition and nutritional values of sausage made from beef meat substituted by different levels of whole amaranth meal.

Components	Frozen storage time (month)	Whole amaranth meal substitute ratios				
		0% (Control)	5%	10%	15%	20%
Moisture (%)	0	57.55	57.01	56.58	55.84	55.16
	1	57.23	56.75	56.35	55.66	55.04
	2	56.85	56.51	56.23	55.58	54.91
	3	56.61	56.36	56.09	55.40	54.79
Crude protein (%)	0	15.61	15.06	14.89	14.73	14.51
	1	15.40	14.88	14.73	14.61	14.42
	2	15.11	14.71	14.65	14.52	14.33
	3	15.01	14.63	14.55	14.43	14.24
Ether extract (%)	0	18.49	18.01	17.63	17.23	17.01
	1	19.01	18.44	18.00	17.50	17.22
	2	19.58	18.77	18.18	17.62	17.37
	3	19.92	18.96	18.35	17.85	17.54
Ash (%)	0	2.90	2.95	3.01	3.34	3.75
	1	2.97	3.02	3.09	3.43	3.81
	2	3.15	3.18	3.19	3.54	3.90
	3	3.24	3.27	3.31	3.63	3.99
Carbohydrate (%)	0	5.45	6.97	7.89	8.86	9.57
	1	5.39	6.91	7.83	8.80	9.51
	2	5.31	6.83	7.75	8.74	9.49
	3	5.26	6.78	7.70	8.69	9.44
Nutritional values kcal/100g	0	250.25	249.60	249.06	248.57	248.46

Each value is the average of three replicates

Table (2): Freshness tests, physico-chemical properties and cooking parameters of sausage made from beef meat substituted by different levels of whole amaranth meal.

Components	Frozen Storage time (month)	Whole amaranth meal substitute ratios				
		(Control) 0 %	5%	10%	15%	20%
TVN (mg/100g)	0	8.65	8.50	8.02	7.46	6.92
	1	9.95	9.40	8.72	8.16	7.28
	2	10.45	10.37	10.02	9.71	8.91
	3	12.56	11.50	11.42	11.26	10.46
TBA (mg/kg)	0	0.561	0.527	0.481	0.451	0.421
	1	0.612	0.571	0.552	0.491	0.451
	2	0.883	0.636	0.582	0.543	0.487
	3	0.869	0.745	0.699	0.682	0.594
pH values	0	5.84	5.90	5.94	5.99	6.01
	1	5.96	5.99	6.01	6.08	6.10
	2	6.09	6.08	6.08	6.13	6.16
	3	6.18	6.13	6.16	6.18	6.19
WHC (cm^2/0.3g)	0	3.00	2.45	2.39	1.81	1.59
	1	2.56	2.2	2.03	1.56	1.37
	2	1.88	1.81	1.71	1.39	1.15
	3	1.67	1.40	1.33	1.21	1.01
Plasticity (cm^2/0.3g)	0	2.2	1.75	1.60	1.39	1.17
	1	1.95	1.47	1.44	1.31	1.02
	2	1.75	1.36	1.29	1.20	0.83
	3	1.70	1.23	1.11	1.09	0.61
Frying loss (%)	0	7.68	7.11	6.86	6.75	6.65
	1	7.48	7.39	7.22	7.11	6.99
	2	8.11	7.99	7.67	7.50	7.21
	3	8.67	8.47	8.11	7.94	7.77
Cooking yield for frying (%)	0	92.32	92.89	93.14	93.25	93.35
	1	92.02	92.61	92.78	92.89	93.01
	2	91.89	92.019	92.33	92.50	92.79
	3	91.33	91.53	91.89	92.60	92.23
Cooking loss (%)	0	12.88	10.22	10.08	9.70	9.30
	1	13.35	11.11	10.95	10.11	9.77
	2	13.93	11.60	11.55	10.67	10.28
	3	14.37	11.89	11.81	11.09	10.85
Cooking yield for cooking (%)	0	87.12	89.78	89.92	90.30	90.70
	1	86.65	88.89	89.05	89.89	90.23
	2	86.07	88.40	88.45	89.33	89.72
	3	85.63	88.11	88.19	88.91	90.23

Each value is the average of three replicates

Microbiological quality of sausage:

The total viable bacterial count is widely used as an indicator microbiological quality of food. Data in Table (3) indicated that the total viable bacterial count was ranged from $67x10^3$ to $98x10^3$ cfu/g for sausage substituted with 20% whole amaranth meal and sausage control, respectively. This number of bacteria is more acceptable for prepared food product especially meat products. The total viable bacterial count was decreased after storage until second month, but the decreasing was not more than logarithmic cycle. The decreasing of total viable bacterial count related to physical effect of freezing on bacteria. Moreover most of water in the product changed from liquid form to solid form which can not be use by bacteria. After four months the total viable bacterial count was increased by one logarithmic cycle related to that bacteria already resist freezing environmental and the changing in some properties of sausage. Count of psychrophilic bacteria took the same trend of total viable bacterial count in fresh sausage or after storage. Counts of yeast and moulds in fresh product were less than 15 cfu/g as American public health method counting. The small count of yeast and moulds in fresh sausage may be coming from some ingredient specially spices. After first month yeast and moulds can not be detected, this may that yeast and molds can not resist for freezing environmental. Counts of lactic acid bacteria in sausage are acceptable and ranged from $50x10^2$ to $98x10^2$ in sausage substituted with 5% of whole amaranth meal and control sausage, respectively. Concerning coliform group, it's counts were less than 30 cfu/g. The coliform group may come in sausage from meat. After freezing, coliform group was not detected.

Table (3): Microbiological quality of sausage made from beef meat substituted by different levels of whole amaranth meal.

Microbiological group	Frozen storage time (month)	Whole amaranth meal substitute ratios				
		Control 0%	5%	10%	15%	20%
Total Viable bacterial count	0	$98x10^3$	$78x10^3$	$75x10^3$	$67x10^3$	$67x10^3$
	1	$44x10^3$	$39x10^3$	$37x10^3$	$33x10^3$	$33x10^3$
	2	$85x10^3$	$77 x10^3$	$67 x10^3$	$64 x10^3$	$65 x10^3$
	3	$70x10^4$	$65 x10^4$	$59 x10^4$	$63 x10^4$	$61 x10^4$
Psychrophilic bacteria	0	$45x10^3$	$41x10^3$	$39x10^3$	$35x10^3$	$38x10^3$
	1	$42x10^3$	$38 x10^3$	$33 x10^3$	$30 x10^3$	$35 x10^3$
	2	$66 x10^3$	$59 x10^3$	$44 x10^3$	$47 x10^3$	$49 x10^3$
	3	$49 x10^4$	$44 x10^4$	$39 x10^4$	$37 x10^4$	$39 x10^4$
Yeast and moulds	0	<15	<15	<15	<15	<15
	1	N.D.	N.D.	N.D.	N.D.	N.D.
	2	N.D.	N.D.	N.D.	N.D.	N.D.
	3	N.D.	N.D.	N.D.	N.D.	N.D.
Lactic acid bacteria	0	$98x10^2$	$50x10^2$	$72x10^2$	$75x10^2$	$60x10^2$
	1	$10.5x10^2$	$9.9x10^2$	$8.8x10^2$	$7.7x10^2$	$7x10^2$
	2	$55x10^2$	$49x10^2$	$41x10^2$	$44x10^2$	$39x10^2$
	3	$10.9x10^2$	$99x10^2$	$83x10^2$	$79x10^2$	$71x10^2$
Coliform group	0	<30	<30	<30	<30	<30
	1	N.D.	N.D.	N.D.	N.D.	N.D.
	2	N.D.	N.D.	N.D.	N.D.	N.D.
	3	N.D.	N.D.	N.D.	N.D.	N.D.

N.D. not detected

Texture parameters of sausage:

The changes in textural properties of sausage are due to the associated changes in the physico-chemical properties and the whole amaranth meal replacement ratio. It can be also observed that, the texture parameters (hardness and softening) behaved similarly in describing the textural qualities, so that any of them may be effectively considered as representative parameter for texture evaluation of whole amaranth meal replacement ratio.

Effect of whole amaranth meal replacement ratio and storage time on the texture characteristics of sausage:

Data, mean of three replicates of sausage ± standard errors of (F_{max}) max force or puncture force (N), max deformation (mm), hardness (N/mm) and softening (%) are presented in Tables (4-5). These data as an indicator of hardness were measured by shearing through the 1 cm height to 50% of their original height at a speed of 5 mm/min. Maximum force and hardness for sausage made from meat and different whole amaranth meal substitute ratios were higher than control samples (made from meat only), indicating that the replacement meat with whole amaranth meal in sausage improved the texture parameters. So, it is very useful in sausage processing, handling and storage. On the other hand, maximum force and hardness were decreased with increasing in frozen storage time for all samples. In the same time softening values in the same tables were decreased with increasing in frozen storage time. The changes in texture parameters of raw and cooked sausage in this study could be generally linked to the chemical changes during cooking. Protein and starch present in sausage play an important role in the cooking quality because they can absorb water. The same results were observed by **(**Kumar and Sharma, 2004**)**.

The changes in texture are related to the adding whole amaranth meal and to the physiological properties. Probably changes in protein and starch.

Effect of cooking on texture parameters:

The texture of cooked sausage is expected to be dependent on the texture of raw sausage, and hence adding whole amaranth meal which affected the texture of raw sausage also affected the texture of cooked sausage. Trends of texture loss were similar for all samples during cooking, cooked of control sample showed lower texture values (max force and hardness) than samples made from replacement meat with whole amaranth meal and this trend was consistent during frozen storage. Any how this parameter is important to calculate other parameters which describe the texture and energy such as hardness, softening parameters.

In the same time the texture parameters was obtained in penetration test which must be neglected that penetration test depends on certain point while compression test depends on all points of the sausage. The similar trend to those reported by Andres, *et al.* (2006).

Finely, whole amaranth meal doses improve the texture of the sausage after processing and therefore give a good end product.

Table (4): Texture parameters (Penetration test) for frozen stored sausage

Whole amaranth meal substitute ratio	Frozen storage time	Puncture force	Max deformation	Hardness	Softening
	(month)	N	mm	N/mm	%
control 0%	0	125.15±2.08	4.62± 0.07	27.09	39.27
	1	117.43±2.52	4.71± 0.02	24.93	38.69
	2	113.85±1.85	4.73± 0.17	24.07	38.05
	3	109.97±3.10	4.72± 0.10	23.30	36.71
5%	0	128.05±1.57	4.53± 0.19	28.27	38.92
	1	123.08±2.15	4.56± 0.07	26.99	38.27
	2	122.31±2.08	4.61± 0.06	26.53	38.77
	3	118.17±3.71	4.64± 0.13	25.47	37.66
10%	0	133.00±2.13	4.55± 0.05	29.23	36.08
	1	125.92±2.05	4.55± 0.01	27.67	35.44
	2	123.38±1.48	4.56± 0.05	27.06	35.15
	3	121.81±3.42	4.88± 0.07	24.96	34.96
15%	0	136.11±3.24	4.46± 0.11	30.52	33.90
	1	129.84±2.41	4.48± 0.17	28.981	32.21
	2	126.84±2.02	4.51± 0.14	28.121	32.17
	3	124.08±3.84	4.55± 0.10	27.271	32.05
20%	0	139.02±1.01	4.55± 0.09	30.551	33.29
	1	133.14±1.88	4.59± 0.04	29.01	32.89
	2	130.43±2.24	4.63± 0.03	28.17	32.30
	3	128.74±2.94	4.69± 0.07	27.45	32.41

Table (5): Texture parameters (Compression test) for frozen stored sausage

Whole amaranth meal substitute ratio	Frozen storage time	Maximum Force	Max deformation	Hardness	Softening
	(month)	N	mm	N/mm	%
Control 0%	0	208.42±2.71	5.00 ± 0.00	41.68	39.39
	1	197.85±1.38	5.00 ± 0.00	39.57	37.78
	2	193.49±1.57	5.00 ± 0.00	38.70	37.45
	3	189.67±2.91	5.00 ± 0.00	37.94	37.39
5%	0	213.96±1.63	5.00 ± 0.00	42.79	38.31
	1	201.68±1.84	5.00 ± 0.00	40.34	36.53
	2	195.14±2.18	5.00 ± 0.00	39.03	35.85
	3	191.28±3.11	5.00 ± 0.00	38.26	35.70
10%	0	218.60±2.15	5.00 ± 0.00	43.72	36.21
	1	204.33±2.73	5.00 ± 0.00	40.87	35.40
	2	197.69±1.91	5.00 ± 0.00	39.54	35.25
	3	194.55±3.65	5.00 ± 0.00	38.91	35.19
15%	0	224.85±1.92	5.00 ± 0.00	44.97	35.51
	1	212.03±2.67	5.00 ± 0.00	42.41	33.50
	2	206.11±2.38	5.00 ± 0.00	41.23	32.37
	3	203.88±3.11	5.00 ± 0.00	40.78	32.32
20%	0	230.09±1.45	5.00 ± 0.00	46.02	35.24
	1	217.54±1.81	5.00 ± 0.00	43.51	32.89
	2	215.05±2.57	5.00 ± 0.00	43.01	32.58
	3	207.99±2.84	5.00 ± 0.00	41.60	31.25

Sensory properties of sausage made from beef meat substituted by different levels of whole amaranth meal:

Sensory attributes are the main factor affects on quality of food products especially meat products. Sensory attributes included color, flavor, taste, hardness, juiciness and overall acceptability. Hardness the extent to which moisture plasticizes the protein matrix of meat determines its hardness, that is, the amount of work required to fracture the meat. Fat, on the other hand, lubricates the protein matrix and creates weaknesses in the meat that facilitate fracturing. Although, the perception of texture may take place throughout the entire masticator process. Juiciness is considered a very desirable characteristic in a wide variety of foods, partly because it provides an excellent texture contrast. Juiciness has been defined as ‘the amount of juice released on mastication.

The organoleptic properties of sausage were generally the final guide of the quality from the consumer's point of view. Thus, it was beneficial to make a comparative sensory evaluation for fresh sausage and their corresponding substituted by whole amaranth meal. All samples (fresh and substituted) were evaluated organoleptically by ten panelists for the forementioned attributes, according to given scores (20 degrees for each attribute except overall acceptability which has 100 degrees) and the mean values of scores were statistically analyzed ($\alpha = 0.05$) using analysis of variance (ANOVA) and least significant difference (LSD), as presented in Table (6).

Color:

Color is considered very important item of sausage and most of meat products. Statistical analysis for color data in Table (6) indicated that there are no significant differences ($P>0.05$) between the color of sausage substituted with 0, 5, or 10 % whole amaranth meal. In the same time the differences between the color of control sausage and the color of sausage substituted with 15 or 20 % whole amaranth meal were significant ($P<0.05$). The average of the obtained scores ranged between 18.44 ± 0.123 and 15.41 ± 0.194 for sausage substituted with 0 and 20 % whole amaranth meal, respectively. On the other hand, differences in the color of sausage frozen stored for 0, 1, 2 or 3 months were significantly differed (P<0.05) except the difference between 1st and 2nd months which was not significant (P>0.05). The average of the obtained scores ranged between 18.02 ± 0.201 and 16.88 ± 0.243 for sausage frozen stored for 0 and 3 months, respectively.

Flavor:

Statistical analysis for flavor data in Table (6) indicated that there are significant differences (P<0.05) between the flavor of sausage substituted with 0 and 10, 15 or 20 % whole amaranth meal. In the same time the differences between the flavor of control sausage and the flavor of sausage substituted with 5 % whole amaranth meal was non significant (P>0.05). The average of the obtained scores ranged between 19.25 ±0128 and 12.88 ±0.247 for sausage substituted with 0 and 20 % whole amaranth meal, respectively. On the other hand, differences in the flavor of sausage frozen stored for 0, 1 or 2 months were non significant differences (P>0.05. The average of the obtained scores ranged between 17.14 ±0.371 and 16.29 ±0.404 for sausage frozen stored for 0 and 3 months, respectively.

Taste:

Statistical analysis for taste data in Table (6) indicated that there are no significant differences (P>0.05) between the taste of sausage substituted with 5 and 10 whole amaranth meal. The average of the obtained scores ranged between 18.94 ±0.143 and 17.26 ±0.298 for sausage substituted with 0 and 20 % whole amaranth meal, respectively. On the other hand, differences in the taste of sausage frozen stored for 0 and 1 or 2 and 3 months were non significant differences (P>0.05(The average of the obtained scores ranged between 18.60 ± 0.194 and 17.60 ± 0.262 for sausage frozen stored for 0 and 3 months, respectively.

Hardness:

Statistical analysis for hardness data in Table (6) indicated that there are no significant differences (P>0.05) between the taste of sausage substituted with 0 and 5 or 15 and 20 % whole amaranth meal. The average of the obtained scores ranged between 18.65 ± 0.142 and 16.88 ± 0.233 for sausage substituted with 0 and 20 % whole amaranth meal, respectively. On the other hand, differences in the hardness of sausage frozen stored for 0, 1 and 2 months were non significant differences (P>0.05). The average of the obtained scores ranged between 18.02 ±0.183 and 17.42 ±0.238 for sausage frozen stored for 0 and 3 months, respectively.

Juiciness:

Statistical analysis for juiciness data in Table (6) indicated that there are no significant differences (P>0.05) between the juiciness of sausage substituted with 0 and 5 or 15 and 20 % whole amaranth meal. The average of the obtained scores ranged between 18.70 ± 0.188 and 16.18 ± 0.242 for sausage substituted with 0 and 20 % whole amaranth meal, respectively. On the other hand, differences in the juiciness of sausage frozen stored for 0, 1 and 2 months were non significantly differed (P>0.05). The average of the obtained scores ranged between 18.08 ± 0.226 and 17.37 ± 0.306 for sausage frozen stored for 0 and 3 months, respectively.

Overall acceptability:

Statistical analysis for over all acceptability data in Table (6) indicated that there are no significant differences (P>0.05) between the over all acceptability of sausage substituted with 0, 5 and 10 % whole amaranth meal. They are significantly differed than sausage substituted with 15 or 20 % whole amaranth meal. The average of the obtained scores ranged between 94.15 ab±0.262 and 88.43 d ±0.440 for sausage substituted with 0 and 20 % whole amaranth meal, respectively. On the other hand, there are significant differences between over all acceptability of sausage frozen stored for 0 and 1, 2 or 3 months. The average of the obtained scores ranged between 93.62 ±0.420 and 91.36 ±0.452 for sausage frozen stored for 0 and 3 months, respectively.

Table (6): Sensory properties of sausage made from beef meat with substituted by different levels of whole amaranth meal.

Sensory attributes	Whole amaranth meal substitute ratios	Frozen storage time (month)				Average
		0	1	2	3	
Color	0 %	18.70±0.153	18.55±0.302	18.30±0.260	18.20±0.249	18.44^{ab}±0.123
	5 %	19.20±0.416	18.80±0.327	18.80±0.300	18.5±0.183	18.83^{a}±0.158
	10 %	18.80±0.327	18.30±0.367	17.75±0.083	17.25±0.375	18.03^{b}±0.176
	15 %	17.10±0.233	16.60±0.340	16.50±0.289	15.65±0.388	16.46^{c}±0.174
	20 %	16.30±0.213	15.40±0.600	15.15±0.198	14.80±0.260	15.41^{d}±0.194
	Average	18.02^{a} ± 0.201	17.53^{b} ± 0.255	17.30^{b}± 0.215	16.88^{c} ± 0.243	
	LSD(Storage time)	0.387				
	LSD(addition levels)	0.433				
	LSD(Storage time addition levels)	0.866				
Flavor	0 %	19.55±0.174	19.30±0.300	19.30±0.300	18.85±0.211	19.25^{a} ±0128
	5 %	19.25±0.201	18.80±0.327	18.70±0.343	18.40±0.356	18.79^{a} ±0.158
	10 %	18.05±0.311	18.05±0.311	17.80±0.528	17.30±0.569	17.80^{b} ±0.220
	15 %	15.35±0.334	15.05±0.361	15.00±0.453	14.80±0.490	15.05^{c} ±0.202
	20 %	13.50±0.637	13.35±0.366	12.55±0.450	12.10±0.407	12.88^{d} ±0.247
	Average	17.14^{a} ±0.371	16.91^{a} ±0.360	16.67^{ab} ±0.405	16.29^{b} ±0.404	
	LSD(Storage time)	0.483				
	LSD(addition levels)	0.540				
	LSD(Storage time addition levels)	1.080				
Taste	0 %	19.25±0.281	19.05±0.293	18.80±0.271	18.65±0.308	18.94^{a} ±0.143
	5 %	19.00±0.316	18.65±0.402	18.30±0.436	18.15±0.500	18.53^{ab}±0.208
	10 %	18.50±0.489	18.10±0.547	17.80±0.646	17.60±0.572	18.00^{b} ±0.277
	15 %	18.25±0.496	17.80±0.544	17.45±0.639	17.10±0.649	17.65^{bc}±0.289
	20 %	18.00±0.489	17.45±0.535	17.10±0.653	16.50±0.679	17.26^{c} ±0.298
	Average	18.60^{a} ± 0.194	18.21^{ab} ± 0.220	17.89^{b} ± 0.251	17.60^{b} ± 0.262	
	LSD(Storage time)	0.626				
	LSD(addition levels)	0.700				
	LSD(Storage time * addition levels)	1.400				
Hardness	0 %	18.80±0.213	18.75±0.311	18.65±0.279	18.40±0.348	18.65^{a} ±0.142
	5 %	18.90±0.332	18.60±0.356	18.45±0.431	18.45±0.450	18.60^{a} ±0.192
	10 %	17.85±0.388	17.65±0.380	17.45±0.519	17.10±0.526	17.51^{b} ±0.224
	15 %	17.25±0.335	16.90±0.464	16.80±0.539	16.55±0.513	16.88^{c} ±0.229
	20 %	17.30±0.467	16.90±0.433	16.70±0.467	16.60±0.536	16.88^{c} ±0.233
	Average	18.02^{a} ±0.183	17.76^{ab} ±0.203	17.61^{ab} ±0.227	17.42^{b} ±0.238	
	LSD(Storage time)	0.526				
	LSD(addition levels)	0.588				
	LSD(Storage time * addition levels)	1.176				

Table (6): Continue

Sensory attributes	Whole amaranth meal substitute ratios	Frozen storage time (month)				Average
		0	1	2	3	
Juiciness	0 %	19.05±0.273	18.65±0.289	18.60±0.427	18.50±0.500	18.70[ab]±0.188
	5 %	19.40±0.267	19.10±0.420	18.950.565	18.60±0.682	19.01[a] ±0.243
	10 %	18.85±0.317	18.45±0.450	17.70±0.700	17.85±0.715	18.21[b] ±0.284
	15 %	16.65±0.342	16.30±0.416	16.20±0.484	15.90±0.562	16.26[c] ±0.224
	20 %	16.45±0.425	16.25±0.534	16.00±0.553	16.00±0.477	16.18[c] ±0.242
	Average	18.08[a] ±0.226	17.75[ab] ±0.254	17.49[ab] ±0.293	17.37[b] ±0.306	
	LSD(Storage time)	0.602				
	LSD(addition levels)	0.673				
	LSD(Storage time * addition levels)	1.347				
Over all acceptability	0 %	95.10±0.586	94.20±0.416	94.10±0.407	93.20±0.554	94.15[ab]±0.262
	5 %	96.30±0.448	94.90±0.504	94.20±0.359	93.80±0.663	94.80[a] ±0.287
	10 %	95.20±0.554	94.00±0.577	93.00±0.494	92.70±0.559	93.73[b] ±0.306
	15 %	91.60±0.371	90.90±0.433	90.60±0.521	90.00±0.632	90.78[c] ±0.257
	20 %	89.90±0.706	88.40±0.980	88.30±0.907	87.10±0.795	88.43[d] ±0.440
	Average	93.62[a] ±0.420	92.48[b] ±0.440	92.04[bc] ±0.407	91.36[c] ±0.452	
	LSD(Storage time)	0.740				
	LSD(addition levels)	0.827				
	LSD(Storage time * addition levels)	1.654				

Values represent of 10 panelists (Mean ± S.E.)
a, b There is no significant difference (p≥0.05) between any two averages of whole amaranth meal addition levels, or different storage time have the same superscripts within the same acceptability attribute

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