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SORGHUM PROTEIN CONCENTRATE AND ISOLATE AS A POTENTIAL SOURCE OF HIGH PROTEIN FOR SPAGHETTI MANUFACTURE

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ABSTRACT

Sorghum seed protein products namely, sorghum protein concentrate and sorghum protein isolate were added at 5, 10, 15 and 20% levels of supplementation to wheat flour to raise the nutritional value and spaghetti manufacture. Methods of extraction for both sorghum protein concentrate and isolate, chemical composition and functional properties were studied. Amino acid profiles and scores for all raw materials were measured. All data of spaghetti samples including chemical composition, cooking quality, color characteristics and sensory evaluation were determined. The obtained results revealed that sorghum protein concentrate and isolate extracted by water method and 0.034 N NaoH respectively had higher protein content than the other methods. Also, their functional properties were the best between other methods. The protein content of spaghetti samples supplemented with both sorghum protein concentrate and isolate was increased as the level of supplementation increased. Results of cooking quality showed that, supplementation with both protein concentrate and isolate was increased as the level of supplementation increased. Results of cooking quality showed that, supplementation with both protein concentrate and isolate decreased the cooked weight, volume and increased the cooked loss in spaghetti samples as compared with control. Spaghetti samples were supplemented with protein isolate at all levels. Great change in ΔE values was noticed in spaghetti samples at all supplementation levels with protein isolate. Acceptable high protein spaghetti could be produced using 5% and 10% protein concentrate for sensory characteristics (color and taste) and at supplementation level 5% of protein isolate for sensory characteristics (color and taste) and at supplementation level 5% of protein isolate for color and taste without any significant differences with control.

INTRODUCTION

Sorghum [Sorghum bicolor (L.)] is the fifth most widely grown crop in the world. It is grown in semiarid areas, usually as a dry land crop. Most of the grain produced in these areas is consumed by human as food (Hulse *et al.*, 1980). Sorghum is a major food crop in Africa and Asia. It is the staple food in many areas in sudan. It acts as the major source of protein. Sorghum, like other cereals, is deficient in lysine (Gujska and Khan 1990), two other limiting amino acids are threonine (Harden *et al.*, 1976), and methionine (Hori & Conrad, 1976). Sorghum proteins had higher levels of disulphide bonding than did other cereai grains Mitoru and Blair (1984), Mitaru *et al* (1985) and Hamaker *et al.* (1987).

Wheat, because of its wide area of adaptability, has the greatest potential, for new or expanded food uses.

The wheat protein efficiency ratio is less than half of that of casein. Therefore, by the selective addition of protein to pasta, nutritional value can be improved and the protein content increased (Morad *et al.*, 1980).

In some countries like Egypt, spaghetti can be manufactured from wheat flour (72%) as a popular product. Both types of spaghetti(from semolina or wheat flour) are rich in energy.

Substitution of semolina at 20, 40 and 60% level by whole corn flour and defatted soybean flour at level 8% was carried out to improve the protein quality of produced pasta (Molina *et al.*, 1975).

Supplimentation of semolina with fish protein concentrate was efficient at Both levels 10 and 20% in increasing the protein content and nutritional value of pasta (Kwee *et al.*, 1969) the protein isolate, is usually prepared by several, extraction and precipitation methads (Berardi and Cherry, 1979; El.Tinay and Chandrasekhor, 1960) or precipitated with trichloroacetic acid (TCA) (Drawert *et al.*, 1979). Protein concentrates were prepared by several methods Martinez *et al.* (1970), Lawhon *et al.* (1972) and Cannella and Sodini (1977).}

Functional properties such as water and oil absorption capacities, bulk density and viscosity, calcium precipitability, water hydration, emulsion and foaming properties for protein isolates and concentrate were investigated by (Lawhon and Cater 1971, Sosulski *et al.*, 1976), Manak *et al.* (1980) and Choi *et al.* (1981).

Whole sorghum had a better amino acid composition and a higher protein content than sorghum flour. (endosperm), ground normal and high lysine sorghums were used to produce protein concentrates and by-products by alkaline extraction (Victor 1978).

The objectives of this study were the preparation of different formulas of spaghetti based on wheat flour supplemented with sorghum protein concentrate and isolate extracted with different methods to increase the protein content and improve the quality.

MATERIALS AND METHODS

Materials:

Hard wheat flour (72% extraction) was purchased from the North Cairo Mills Company, Egypt.Sorghum grain (Sorghum bicolor L) local variety (Dorado) was obtained from the Field Crops Research Institute, Agricultural Research Centre, Minsitry of Agriculture, Egypt.

Analytical methods:

Moisture, protein, fat, ash and fibers were determined according to the methods recommended by the A.O.A.C. (1995). Total carbohydrates were calculated by difference.

Amino acid contents were determined at the Central Food and Feed laboratory of the Egyption Agriculture Organization, using Amino acid Analyzer (Beckman system 7300 and Data system 7000). The samples were prepared as described by Moore *et al.* (1958); and Winder and Egyum (1966).

Amino acid score (AAS) was calculated as the following equation:-

$$\text{Aminoacid score} = \frac{\text{(gm amino acid in sample)}}{\text{gm same amino acid in FAO/WHO reference protein (1985)}} \times 100$$

Processing of spaghetti samples:

For preparation of supplemented spaghetti, 5, 10, 15, 20 gm of sorghum protein concentrate and isolate flours were individually added to the basal spaghetti recipe, substituting for an equivalent amount of wheat flour.

The spaghetti samples were prepared in the Food Technology Dep. NRC, Cairo, Egypt, by using pasta matic 1000 simac machine corporation, Millano, Italy. The mixing time was 4-6 min. at 30 rpm under vacuum value of 35 cm Hg. Spaghetti was hydrated under atmospheric air for 15 min., then dried in a cabinet dryer at 40°C for 14 hours. The samples were cooled enough at room temperature, then packed in polyethylene pouches and stored at room temperature until analysis.

Cooking quality of spaghetti, weight increase, volume increase,and cooking loss were evaluated according to the methods described by AACC (1983).

Sensory evaluation: Sensory evaluation of produced spaghetti samples were carried out according to the method described by Hallabo *et al.* (1985).

Statisitical analysis: Sensory evaluation data were statistically analyzed for analysis of variance and to catculate LSD for ranking according to the methods described by McClave and Benson (1991).

Spaghetti color:

Color was measured by using a spectro-Colorimeter (tristimulus color machine) with CIE lab color scale (Hunter, Lab Scan XE, Reston VA.) calibrated with a white standard tile of Hunter Lab Color standard (LX NO. 16379): X = 77.26, Y = 81.94 and Z = 88.14 ($L^* = 92.43$, $a^* = -0.86$, $b^* = -0.16$). Color difference (ȝE) was calculated from a, b and L parameters, using Huter-Scotfield's equation (Hunter, 1975).

$$ȝE = (ȝa^2 + ȝb^2 + ȝL^2)^{½}$$

Where $a = a - a_o$, $b = b - b_o$ and $L = L - L_o$. Subscript "O" indicates color of control. Hue angle ($tg^{-1}b/a$) and saturaion. Index $[\sqrt{a^2 + b^2}]$ were also calculated.

Preparation of sorghum protein concentrates:-

Aqueous extraction procedure: sorghum flour was used for preparation of protein concentrate according to the method described by Lawhon *et al.* (1972).

Ethanol 90% procedure: - Ethanol 90% was used as an organic solvent to remove the residual lipids and sugars with minimum removal of nitrogen a ccording to the method described by Martinez *et al.* (1970).

Acidic n-butanol procedure: - preparation of sorghum protein concentrate was described by Cannella and Sodini (1977).

Dilute salt solution procedure:-

Dilute calcium chloride solution (0.008M, pH 6.3-6.8) was used at room temperature followed by a water washing the sorghum flour to remove sugars, color, flavor components, and the low molecular weight vater soluble proteins as the method of Martinez *et al.* (1970).

Preparation of sorghum protein isolates:-

Water extraction method 50gm of sorghum flour was suspended in 500ml water. The procedure of El-Tinay and Chandrasekhor (1980) was followed.

0.034 N NaoH extraction method : the preparetin of protein isolate from sorghum flour was used according to the method described by Berardi and Cherry, (1979).0.5 N Nacl extraction method: the procedure of Baliga and Lyman (1957) was used Addition of 200ml of 0.5N sodium chloride solution to 50gm of sorghum flour.Urea (6m) extraction method: the extraction of sorghum flour protein was followed according to the method described by Drawert *et al.* (1979).$Cacl_2$ (0.1, 0.5 and 1 N) extraction method:- the procedure of El-Tiney and Chandrasekher (1980) was followed. 50gm of sorghum flour was suspended in 500ml (0.1, 0.5 and 1 $Nacl_2$). The pH of the suspension was adjusted to 10 with 1 M NaoH. All the extraction steps of he procedure were similar to the steps of the equeous procedure.

Functional Properties:-

Water absorption was determined at room temperature by the method of Sosulski *et al.* (1976). The values were expressed as gm of water absorbed by 100gm of protein.

Oil absorption was measured according to the method by Sosulki *et al.* (1976) at room temperature. The values were expressed as gm of oil absorbed by 100gm of protein.

Emulsification capacity (Ec) was determined by the procedure of Beuchat (1977) at room temperature.

Foaming proerties were determined as described by Huffman *et al.* (1975) at room temperature, using 1% protein solution. Foaming capacity (FC) was expressed as the percentage increase in the volume after 30 Sec., and foam stability (Fs) was expressed as the foam volume measured after 10 min.

Protein solubility was determined by the method of King *et al.* (1985) with minor modification. Suspensions containing 1% protein (W/v) were prepared. The suspensions were magnetically stirred for 15min, then centrifuged for 10 min at 4000 rpm. Protein in the supernatant was estimated by the kjeldahl method.

Bulk density (gm/ml) and viscosity (c.p.) were determined according to the method of Choi *et al.* (1981).

Heat coagulobility (%) was determind as the procedure of Kramer and Kwee (1977).

The procedure of Choi *et al* (1981) was followed to determine calcium perceptibility (%).

Water hydration (%) was determined by using humidity – control chamber with mixture of sulfuric acid – water (11 : 89) at 20°C according to Manak *et al.* (1980).

RESULTS AND DISCUSSION

Results of chemical composition for raw materials was presented in Table (1). From these results, it could be noticed that protein content of wheat flour was the highest 13.61% compared with sorghum flour, while fat, ash and fibers contents were 3.75, 2.06 and 2.85%, respectively and higher than those of wheat flour. Total carbohydrates content was relatively closed for both wheat and sorghum flours. These results are in agreement with those obtained by Victor (1978), Saldivar *et al.* (1988), Celis *et al.* (1996) and Malleshi and Klopfenstein (1998). They reported that, major components in sorghum flour were 11-18, 3.03, 1.30 and 77.94 for protein, fat, ash and total carbohydrates.

Table (1). Major Chemical composition of Raw materials. (on dry weight basis)

Components %	Sorghum flour	Wheat flour
Protein	11.16	13.61
Fat	3.75	1.83
Ash	2.06	1.76
Fiber	2.85	2.60
Total carbohydrates	78.34	79.15

Data presented in Table (2) shows amino acids profiles of sorghum products and wheat flour. The results in Table (2) indicated that, sorghum flour had lower content of all essential amino acids than that of sorghum products (sorghum protein concentrate and isolate. The content of essential amino acids of wheat flour was bowered in leucine, cystine, phenylalanine, threonine and valine than the other samples among investigated.

Total essential amino acids for both sorghum products was higher than that of wheat flour and sorghum flour. Total non-essential amino acids was the highest in sorghum products as compared with wheat and sorghum flours.

The contents of alanine, arginine, aspartic acid, proline and serine were lowered while glutamic acid, glycine and histidine contents were higher than those of the other samples.

These results are in agreement with those obtained by Saldivar *et al.* (1988), Malleshi *et al.* (1996) and Malleshi and Klopfenstein (1998).

The amino acid scores for essential amino acids in sorghum products and wheat flour are given in Table (3).

The amino acid scores for essential amino acids in wheat flour and sorghum seed products are given in Table (3). Lysine, threonine and cystine + methionine were the first second and third limiting amino acids, respectively in wheat and sorghum flours.

Table (2). Amino acids profiles of sorghum flour, concentrate, isolate and wheat flour.

Amino acids (g/100g tein	Sorghum flour	Sorghum protein concentrate	Sorghum protein isolate	Wheat flour
Essential amino acids				
Leucine	12.01	12.46	12.74	6.96
Isoleucine	3.58	3.81	4.12	4.25
Lysine	1.88	3.35	2.59	2.14
Cystine	1.40	1.75	1.80	1.33
Methonine	1.61	1.94	2.18	2.00
Phenylalanine	4.66	4.89	5.20	4.48
Tyrosine	3.49	3.67	3.84	3.50
Threonine	2.70	3.12	3.31	2.60
Valine	5.48	4.70	5.87	4.94
Non-essentialaminoacids				
Alanine	7.44	7.76	7.95	3.94
Arginine	3.49	3.75	3.92	3.61
Aspartic acid	6.94	7.11	7.33	4.64
Glutamic acid	19.71	20.24	20.59	26.59
Glycine	2.53	2.82	3.14	3.36
Histidine	1.97	2.16	2.38	2.45
Proline	7.66	7.90	8.16	8.11
Serine	3.58	3.86	4.10	3.85
Total essentlal amino acids	36.81	39.69	41.65	32.20
Total determined amino acids	90.13	95.29	99.22	88.75

In contrast, sorghum protein concentrate and isolate showed that lysine, threonine and isoleucine were the first, second and third limiting amino acids, respectively.

These results are in agreement with those obtained by Neucere and Sumrell (1979). They reported that, lysine, threonine, isoleucine and leucine are the most limiting amino acids in sorghum proteins.

From Table (4), it could be concluded that the values of protein extraction (73.50%), yield (42.81%) and protein recovery (350.23%) of the protein isolate prepared by 6M urea extraction method were higher than the other methods.

These results may be due to the effect of 6M urea extraction method to extraction great amount of protein in the extract solution and the ability of 20% TCA solution to precipitate approximately all the soluble protein in the solution, while the other methods depend on precipitation of protein by adjusting the pH to5 with 3N Hcl.

From the mentioned data it could be concluded that the protein isolate prepared by 0.034 N sodium hydroxide had higher values of protein content than the other methods. These results are in agreement with those obtained by Drawert *et al.* (1979) and El-Tinay *et al.* (1988).

Table (3). Amino acid scores of sorghum flour, protein concentrate, protein isolate and wheat flour.

Essential amino acids. (g/fg)	Wheat flour	Sorghum seed products			Ref. Patern (FAO/WHO 1985)	Amino acids scores (%)			
		Flour	Protein concentrate	Protein isolate		Wheat flour	Sorghum flour	sorghum protein concentrate	Sorghum protein isolate
Leucine	6.96	12.01	12.46	12.74	7.00	99.43	171.57	178.00	182.00
Isoleucine	4.25	3.58	3.81	4.12	4.00	106.25	89.50	95.25	103.00
Lysine	2.14	1.88	2.35	2.59	5.50	38.91	34.18	42.73	47.09
Cystine+methionine	3.33	3.01	3.69	3.98	3.50	95.14	86.00	105.42	103.71
Phenylalanine+tyrosine	7.98	8.15	8.56	9.04	6.80	117.35	119.85	125.888	132.91
Threonine	2.60	2.70	3.12	3.31	4.00	65.00	67.50	78.00	82.75
Valine	4.94	5.78	5.70	5.87	5.00	98.80	109.60	114.00	117.40

Table (4). Yield (%) and protein recovery (%) of sorghum protein concentrate prepared by different methods.

Methods		Protein content%		Protein extraction	*Yield %	**Protein recovery
		Sorghum flour	Protein isolate			
Water		11.16	92.45	46.93	31.58	261.61
0.034 N NaoH		-	93.70	57.64	37.62	315.86
0.5 N Nacl		-	90.13	35.39	25.34	204.65
6 M urea		-	91.30	73.50	42.81	350.23
$Cacl_2$	0.1N	-	90.54	28.41	20.65	167.53
	0.5N	-	91.62	33.62	22.79	187.10
	1N	-	92.17	36.75	27.40	226.30

*Yield = gm protein isolate or concentrate / 100gm flour
** Protein recovery = gm crude protein in yield / gm crude protein in Flour*100

From Table (5), it could be concluded that the values of yield (80.62%) and protein recovery (493.69%) of sorghum protein concentrate prepared by ethanol method were higher than the other methods.

This may be due to that the weight of protein concentrate obtained from this method was higher than the other methods. The protein content of the protein concentrate prepared by water extraction method 73.68% was higher than of other methods.

Table (5). Effect of different methods on yield and protein recovery of protein isolate.

Methods	Protein content (%)		Yield (%)	Protein recovery (%)
	Sorghum flour	Protein concentrate		
Water	11.16	73.68	72.39	477.93
Acidic butanol	-	66.29	76.40	453.81
0.008 $MCacl_2$	-	71.15	67.81	432.32
90% Ethanol	-	68.34	80.62	493.69

Similar results were found by Helmy (1996) in preparation of protein concentrates from cotton seed meals detoxified with several methods.

The results in Table (6) indicated that, the urea extraction method was higher in the percent of total nitrogen in extract (78.82%) than the other methods, but it was lower in the percent of total nitrogen in whey (5.61%). The results, indicated also that protein extractability at levels of $CaCl_2$ normality. Water and 0.5 N Nacl extraction method were low compared with 0.034N NaoH extraction method. Extraction with urea is a less drastic procedure than extraction with alkali, which is likely to cause hydrolysis of amide groups, destruction of amino acids and formation of unnatural compounds (Drawert *et al.*, 1979). NaOH extraction method gave higher protein precipitation % than the other methods (except urea method), at pH 10 of solution the amount of soluble protein was more great and when the pH value was reached to 2.5 by 1 N Hcl, dissociation of

protein was happened . Alkaline extraction at pH 10 was found to be the best method to obtain protein isolate with a high protein content. (El. Tinay *et al.* (1988) and Helmy (1996).

Table (6). Effect of different methods on the preparation of protein isolate.

Methods		Total Nitrogen in extract %	Total Nitrogen in whey %	Total Nitrogen in residue %	Protein precipitation %
Water		73.81	10.32	14.64	85.61
0.034 N NaoH		75.54	9.73	13.48	90.92
0.5 N Nacl		71.69	15.90	11.34	79.46
6 M Urea		78.82	5.61	14.99	94.73
$Cacl_2$	0.1 N	63.74	20.50	14.72	72.51
	0.5 N	66.93	18.46	13.69	75.60
	1 N	69.68	17.82	11.41	82.49

Functional properties of sorghum protein products:

Functional properties of different protein concentrates and isolates were presented in Tables (7) and (8). The data obtained from Table (7) showed that the values of water, oil absorption capacities, nitrogen solubility%, emulsion capacity (EC) and foaming properties of protein concentrate prepared by water method were higher than those the other samples. They reported that sorghum protein products had hiher values of most functional properties than that found in sorghum flour.

The results in the Table (8) showed that all the values of different components of functional proerties for sorghum protein isolate prepared by 0.034N NaOH method were high compared with the other methods. The same trend of results was observed by El-Adawy *et al.* (2001) who found that extractions of protein isolate from lupin seed tend to increase all the components of functional properties than found in lupin flour.

Our results agree well with those reported by Fliedel and Kobrehe (1985), Singh and Singh (1991) and El-Adawy *et al.* (2001).

Gross chemical composition of different protein isolates.

The results in Table (9) showed that the contents of protein, ash and fiber of sorghum protein concentrate prepared by water method were higher than its contents from the other methods.

Fat and total carbohydrates contents were higher in sorghum protein concentrates prepared by 0.008M Ca Cl_2 water method and acidic butanol method respectively compared with the other samples. Similar results were found by Victor (1978) which extracted protein concentrate and isolate from sorghum. From the same table, the results revealed that the protein content of sorghum protein isolate prepared by 0.034N NaOH was higher than the other methods.

Table (7). Functional properties of different protein concentrates.

Methods	Water absorption capacity (g.waterl 100g. sample)	Oil absorption capacity (mloil/g. sample).	Nitrogen solubility %	Emulsion capacity (EC) (ml oil/g sample).	Foaming properties	
					Foam capacity (Fc) ml/g. sample	Foam stability (Fs) ml/g. sample
Water method	219.96	180.64	22.82	53.61	58.56	24.68
Acidic butanol method	197.90	162.52	20.49	48.24	52.75	22.21
0.008 Mcacl$_2$-water method	212.41	174.44	22.04	51.78	56.62	23.84
90% ethanol method	204.02	167.56	21.17	49.71	54.38	22.90

Table (8). Functional properties of different protein isolates.

Methods		Water absorption capacity(g.water/ 100g.sample)	Oil absorption capacity(ml oil/100g.sample)	Nitrogen solubility %	Bulk density g./ml	Viscosity C.P	Heat coagulability %	Calcium-precipitability %	Water hydration %	Emulsion capacity (EC)(ml oil/g sample)	Foaming properties	
											Foam capacity (Fc) ml/g	Foam stability (Fs)ml/g. sample
Water method		390.59	226.82	39.55	0.68	3.49	48.08	54.39	5.98	79.38	94.87	38.72
0.034N NaoH method		395.87	229.88	40.08	0.69	3.52	48.73	55.13	6.06	80.45	96.15	39.24
0.5N Nacl method		380.70	221.12	38.56	0.66	3.29	46.87	53.03	5.83	77.34	92.49	37.75
6M urea method		385.73	223.99	39.06	0.67	3.43	47.48	53.71	5.90	78.40	93.68	38.18
Cacl$_2$	0.1N	382.52	222.13	38.73	0.66	3.34	47.09	53.27	5.86	77.72	92.91	37.92
	0.5N	387.08	224.78	39.20	0.67	3.45	47.65	53.90	5.93	78.66	94.02	38.37
	1.0N	389.41	226.16	39.43	0.68	3.47	47.93	54.23	5.95	79.14	94.58	38.60

Table (9). Chemical composition of different protein concentrates and protein isolates. (on dry weight basis).

Components %	Protein concentrate				Protein isolate						
	Water method	Acidic butanol method	0.008m $cacl_2$-water method	90% Ethanol method	Water method	0.034N NaoH method	0.5 And Nad method	6Mured method	$Cacl_2$ method		
									0.1N	0.5N	1N
Protein	73.68	66.29	71.15	68.34	92.45	93.70	90.13	91.30	90.54	91.62	92.17
Fat	1.60	1.31	1.84	1.45	0.75	0.66	0.80	0.87	0.94	0.98	1.06
Ash	3.45	2.38	2.67	2.89	0.64	0.57	0.76	0.60	0.85	0.90	0.97
Fiber	4.50	3.82	4.10	4.28	0.96	0.89	1.49	1.04	1.13	1.25	1.34
Total carbohydrates	16.77	26.20	20.24	23.04	5.20	4.18	6.82	6.19	6.54	5.25	4.46

Sorghum protein isolates prepared by Ca Cl_2 (0.5N, 1N) method and were high in fat and ash contents compared with the other methods.

Fiber and total carbohydrates contents of sorghum protein isolate prepared by 0.5N Nacl method were the highest as compared with the other investigated samples of protein isolate.

Chemical composition of produced spaghatti samples.

Results in Table (10) showed the chemical composition of produced spaghetti samples. It can be concluded the addition of sorghum protein concentrate and isolate at levels 5, 10, 15 and 20% tend to increase the protein content in spaghetti samples as compared with control. little increase in fat, ash and fibers contents was foundas a result of supplementation. Total carbohydrates content was reduced in spaghetti samples and the reduction in samples supplemented with sorghum protein isolate was greater than that occurred in samples supplemented with sorghum protein concentrate. The results are in agreement with the results obtained by Nielsen *et al.*, (1980), Bahnassey *et al.* (1986) and Szczopa *et al.* (1997).

Table (10). Chemical composition of produced spaghetti samples (on dry weight basis).

Components %	Concentrate samples								
	Control	Spaghetti supplemente with sorghum proteins				Speghette supplemental with sorghum trotein Isolate			
		5%	10%	15%	20%	5%	10%	15%	20%
Protein	12.30	15.89	19.54	23.20	26.81	16.92	21.56	26.27	30.93
Fat	0.91	0.96	1.04	1.12	1.20	0.93	0.96	0.99	1.02
Ash	0.80	0.95	1.13	1.29	1.47	0.82	0.84	0.87	0.91
Fiber	0.65	0.87	1.08	1.31	1.53	0.69	0.72	0.77	0.81
Total carbohydrates	85.34	81.33	77.21	73.08	68.99	80.64	75.92	71.10	66.33

Cooking quality of Sp ----------samples.

From Table (11), the results showed that, spaghetti control sample was the highest in values of change in cooked weight and volume and was the lowest in value of change in cooked loss. The rate of reduction in values of change in cooked weight and volume were reduced with high percent in supplemented spaghetti samples with sorghum protein concentrate than that of spaghetti samples supplemented with sorghum protein isolate at the same levels.

Also, from the same table, the rate of change in cooked weight was increased in spaghatti samples supplemented with sorghum protein isolate as compared with samples supplemented with sorghum protein concentrate at all levels. The obtained results are in agreement with those obtained by Siwawj (1994).

Reported that, who suplemented wheat flou with 10, 15, 20 and 25% of sorghum flour in manufactur of macaroni and the results of cooking quality were improved. Similar findings were obtained by Molina *et al.* (1975), Nielsen *et al.* (1980) and Morad *et al.* (1980).

Table (11). Cooking quality of spaghetti supplemented with sorghum protein concentrate and isolate at different levels.

Spaghetii samples	Change in cooked weight		change in cooked volume		Change in cooked loss	
	%	Relative value	%	Relative value	%	Relative value
Control	310.84	100	291.71	100	6.46	100
Spaghetti supplemented with sorghum protein concentrate at levels of:						
5%	282.15	90.77	268.32	91.98	6.61	102.32
10%	273.38	87.95	249.54	85.54	6.98	108.05
15%	260.62	83.84	237.19	81.31	7.32	113.31
20%	247.80	79.72	221.46	75.92	778	120.43
Spaghetti supplemented with sorghum protein isolate at levels of:						
5%	306.21	98.51	280.26	96.07	6.84	105.88
10%	296.50	95.38	267.42	91.67	7.41	114.71
15%	287.43	92.46	259.74	89.04	7.79	120.59
20%	274.62	88.34	241.31	82.72	8.16	126.31

Table (12). Hunter color values of spaghetti supplemented with sorghum protein concentrate and isolate at different levels.

Samples	L	a	B	a/b	Saturation	Hue	ΔE
Control	86.31	1.06	11.55	0.09	11.59	84.75	-
Spaghetti supplemented with sorghum protein concentrate at levels of:							
5%	86.22	1.58	11.85	0.13	11.95	82.40	0.61
10%	83.92	2.79	13.18	0.21	13.47	78.04	3.37
15%	79.90	3.99	15.21	0.26	15.72	75.29	7.94
20%	78.64	4.15	14.45	0.29	15.03	73.96	8.76
Spaghetti supplemented with sorghum protein isolate at levels of:							
5%	80.58	2.41	12.29	0.19	12.52	78.88	5.93
10%	76.49	2.67	12.43	0.21	12.71	77.86	9.99
15%	72.64	3.36	12.97	0.25	13.40	75.47	13.93
20%	71.54	3.56	13.64	0.26	14.09	75.37	15.13

Color values of spaghetti samples were presented in table (12) and showed that the addiation of both sorghum proteins to spaghetti samples tend to reduced (L) lightness values for samples than control.

The effect was great and clear in samples supplemented with sorghum protein isolate while, values of (a) redness for supplemented samples with sorghume protein concentrate were increased than the same values for spaghetti samples supplemented with sorghum protein isolate at the same supplementation level (except 5% level). The values of (b) yellowness in samples supplemented with sorghum protein concentrate were increased than those for samples supplemented with sorghum protein isolate (except 5% level).

Saturation values of supplemented spaghetti samples with both sorghum proteins (concentrate and isolate) were raised while, hue values in the same samples were reduced. Compared with control. Results of ΔE values indicated that the highest change in samples occurred in all supplementation levels with protein isolate and the lowest change was found in samples contained 5% sorghum protein concentrate. The obtained results are in agreement with those obtained by Haber *et al* (1978), who examined spaghetti processed from wheat hard red spring and soft red winter wheat supplemented with six high protein derivatives from soybean and cotton seed meal and found that spaghetti processed from control gave the best overall quality and the highest color score. Who reported that, high protein materials such as soybean and cotton seed meals were used with wheat flour to made spaghetti and the color was decreased in most samples.

Sensory evalution of spaghetti samples.

Results of sensory evaluation for spaghetti samples are presented in Table (13). From these results, control sample was the highest in all sensory attributes among the samples investigated. Spaghetti samples supplemented with sorghum protein concentrate had high score values for all sensory charactristcs compared with results of samples supplemented with sorghum protein isolate. There was no significant differences in appearance regarding samples supplemented with sorghum protein concentrate between control, 5 and 10%. Also no effect was observed in appearance of samples Supplemented with sorghum protein isolate between 5 and 10% or 15 and 20%. In regard to color, there was no significant differences between control sample, samples supplemented with 5, 10, 15% sorghum protein concentrate and sample contained 5% sorghum protein isolate. The same result was observed in samples supplemented with 10 and 15% sorghum protein isolate. Supplementation of spaghetti with protein concentrate or isolate had no effect between levels 5 and 10% or at 5% respectively. at levels 15 and 20% for samples supplemented with protein concentrate or at 10, 15and 20% for samples supplemented ith protein isolate, no significant differences were observed for taste. Control sample and samples supplemented with 5 and 10% protein concentrate or 5% protein isolate were similar in taste. The results of tenderness indicated that, supplementation with protein concentrate caused significant differences between levels 10, 15 and 20% but 5% was similar to control sample. Protein isolate samples different in tenderness between them, stickiness of samples containg 5 and 10% protein concentrate and 5% protein isolate similar to control sample. Samples containg 20% protein concentrate and 15% protein isolate were similar in stickiness property.

Table (13). Statistical parameters of mean values of sensory evaluation of spaghetti samples

Characteristics	Control	Protein concentrate 5%	Protein concentrate 10%	Protein concentrate 15%	Protein concentrate 20%	Protein isolate 5%	Protein isolate10%	Protein isolate 15%	Protein isolate 20%	(LSD)
Appearance(10)	9.02^{A}	8.64^{A}	8.50^{A}	8.20^{AB}	7.78^{B}	7.56^{B}	7.28^{B}	5.60^{C}	5.22^{C}	0.82
Color (10)	9.46^{A}	9.20^{A}	9.12^{A}	8.76^{A}	8.58^{B}	9.12^{A}	7.42^{C}	7.06^{C}	6.64^{D}	0.87
Taste (10)	8.70^{A}	8.56^{A}	8.34^{A}	7.62^{B}	7.50^{B}	8.40^{A}	7.74^{B}	7.24^{B}	6.88^{B}	0.96
Tenderness(10)	7.74^{A}	7.52^{A}	7.23^{AB}	7.06^{B}	6.80^{BC}	7.26^{AB}	7.02^{B}	6.68^{BC}	6.40^{C}	0.66
Stickiness (10)	7.38^{A}	7.14^{A}	6.90^{A}	6.40^{B}	5.70^{BC}	7.08^{A}	6.72^{AB}	5.82^{BC}	5.26^{C}	0.98
Total (50)	42.3	41.06	39.73	37.86	34.94	39.42	34.18	30.40	27.40	

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استخدام البروتين المركز والمفصول للسورجم كمصدر عالي للبروتين في صناعة المكرونة الاسباجتي

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تم استخدام بروتين السورجم المركز والمفصول بنسب استبدال ٥، ١٠، ١٥ وكذلك ٢٠% من دقيق القمح بغرض رفع القيمة الغذائية في صناعة المكرونة الاسباجتي. وتم دراسة طرق الاستخلاص لكل من البروتين المركز والمفصول والتركيب الكيماوي والصفات الوظيفية وكلك تركيب الأحماض الأمينة والأحماض الأمينية المحددة Chemical score لكل المواد الخام المستخدمة. وأيضا تم تقدير التركيب الكيماوي وخواص جودة الطهي وصفات اللون وكذلك التقييم الحسي لعينات الاسباجتي. وأوضحت النتائج أن البروتين المركز المحضر بطريقة الماء وكذلك البروتين المفصول المحضر بطريقة الصودا كانا الأعلى في محتوى البروتين وأيضا الأفضل في كافة الصفات الوظيفية المختلفة بالمقارنة مع الطرق الأخرى.

ووجد أن محتوى البروتين لعينات الاسباجتي يزداد بزيادة مستوى الاستبدال ولوحظ أن كلا نوعي بروتين السورجم (المركز، المفصول) أدى إلى انخفاض الوزن والحجم وزيادة الفقد نتيجة للطبخ في عينات الاسباجتي بالمقارنة مع الكنترول.

وأظهرت النتائج حدوث انخفاض في قيم lightness (L) لعينات الاسباجتي المحتوية على بروتين مركز على جميع مستويات الاستبدال كما لوحظ حدوث تغير كبير في اللون إلى اللون الداكن كنتيجة لزيادة قيم Eؤ في عينات الاسباجتي المحتوية على بروتين مفصول على جميع نسب الاستبدال.

وقد أمكن الحصول على عينات اسباجتي عالية البروتين ذات خصائص حسية مقبولة عند نسب استبدال ٥، ١٠% بالبروتين المركز اللون والطعم على الترتيب وكذلك على مستوى استبدال ٥% بالبروتين المفصول للون والطعم بدون حدوث أي تغيرات معنوية بالمقارنة مع الكنترول. وأظهرت النتائج أنه يمكن إنتاج مكرونة أسباجتي مقبولة الصفات الحسية باستبدال دقيق القمح حتى مستوى ١٥% بروتين سورجم مركز وكذلك ١٠% بروتين سورجم مفصول.