

Quality Characteristics of Chicken Sausage Formulated with Chia Seeds

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Abstract: The aim of this investigation was to improve the physicochemical and sensory characteristics of chicken sausage formulated with partial replacement of the whole chicken meat with whole chia seed powder (WCSP) at levels 0, 2, 4, and 6%. The resultant sausages were evaluated for proximate composition and fatty acid profile, pH value, sensory properties (taste, texture, odor, color and general acceptability), water holding capacity, cooking loss, cooking yield and shrinkage during refrigerated storage period at $4\pm 1^\circ\text{C}$ for 21 days. The results regarding that the substitution of chicken meat with WCSP improved the fatty acids profile, which increased the total poly unsaturated fatty acids and reduced the omega-6 to omega-3 ratio. Moreover, improved texture, odor and taste, decreased the cooking loss and shrinkage percentages while increased the cooking yield percentage and water holding capacity. Control sample presented lower ($p < 0.05$) pH values compared with treatments formulated with chia seeds. All pH values declined significantly during 21 days of refrigerated storage at $4\pm 1^\circ\text{C}$. All of the resultant chicken sausage was acceptable. No differences were detected in the sensory characteristics of resultant chicken sausage (control, 2 and 4% whole chia seed powder) but significant differences with 6%.

Keywords: Chicken sausage, polyunsaturated fatty acid, pH value, WHC.

INTRODUCTION

Increased understanding of the relationship between diet and some specific healthy nutritional components has led to a new view of the effect of nutritional components on physiological function and human health. This awareness prompted consumers to become more health conscious, directing their attention towards healthy and nutritious foods with additional health-promoting functions, such as functional meat products (Olmedilla-Alonso *et al.*, 2013).

It is important to correlate between food, health and consumer desires. Chicken meat and its diverse products can accomplish the healthy and delicious food combination. It is easy to prepare and serve furthermore, economical compared to other kinds of meat (Hassanin *et al.*, 2017). It is a good source of high biological value protein (20-22%), has low fat content and less saturated when compared to other types of meat besides low energy value (Candan and Bagdatli, 2017). It is worth mentioning that the fat composition of chicken meat favorable which contained major amounts of polyunsaturated fats, especially the omega-6 or n-6 linoleic acid (18:2 n-6) (Kishowar *et al.*, 2004). Furthermore, it provided essential vitamins (from group B mainly thiamin, riboflavin, pyridoxine, and pantothenic acid) which didn't decline significantly during cooking, besides some lipophilic vitamins like E and K. Moreover, it contained minerals like iron, zinc, and copper (Barroeta, 2007; Marangoni *et al.*, 2015). Chicken meat and their products characterized for healthy, nutritious, favorable and inexpensive foods when compared with other kinds of meat besides having high cooking yield and low shrinkage percent (Yeung and Yee, 2002; Barroeta, 2007). Many people noticed that there are some problems appeared after cooking chicken meat as a result of over cooking; these problems are summarized in losing moisture which led to rubbery texture making the meat hard to chew and swallow. It also gave the meat tasteless. Another reason

for the rubbery or woody breast meat maybe related to the nature of the muscle fibers (Tornberg, 2005). Coró *et al.* (2003) and Lyon *et al.* (2004) reported that the texture of meat influenced by processing parameters, the quantity of intramuscular fat, water holding capacity (WHC), actomyosin complex, freezing method, cooking and cooking time. These considerations usually affect the muscle fibers directly.

Salvia hispanica (L.) is an oilseed commonly known as chia. Chia seeds have been considered nutritious, nutraceutical, beneficial and important food for human health and nutrition because of their high content of α linolenic fatty acid and beneficial health effects arising from consuming the ω -3 fatty acids it contained. Chia seed is composed of protein (15-25%), fats (30-33%), carbohydrates (26-41%), high dietary fiber (18-30%) and ash (4-5%); it also contained a high amount of antioxidants (Ixtaina *et al.*, 2008). It is a very good source of proteins which contain a good essential amino acid balance (Kulczynski *et al.*, 2019). It contained heavy metal at safe levels, with the permissible limits of metal levels for food safety, and the seed is also free from mycotoxins (Bresson, 2009). Another feature look of chia seed is that it is gluten free (Bueno *et al.*, 2010). The dry and clean seed can be kept for years because it has antioxidants that prevent the deterioration of essential oils. One of the main properties of this seed is that it is natural source of omega-3 (corresponding to 75 % of the total seed oil) and omega-6. Ayerza and Coates (2005) declared that the seeds presented as an extraordinary source of omega-3 fatty acids, linolenic acid which is essential FA and inception derivative long-chain FA, especially eicosapentaenoic acid (EPA, C20:5 n3) and docosahexaenoic acid (DHA, C22:6 n3). Moreover, Ayerza (2011) found that the highest known percentage of α -linolenic fatty acid, up to 67.8% is concentrated in chia oil. It also has significant concentrations of natural antioxidants, primary and synergistic these are

particularly polyphenols such as chlorogenic acid, caffeic acid, quercetin and kaempferol, soluble and insoluble fiber, vitamins and minerals (Oliveira-Alves *et al.*, 2017; Rahman *et al.*, 2017). The seed also has significant amount of dietary fiber compared with other fruits and seeds. When the seed is placed in water, it exuded a mucilaginous polysaccharide that surrounds it. This mucilage has interesting properties for food, care and pharmaceutical industries. It has been reported that when mucilage from chia is consumed and aid for digestion; therefore the whole seed is a nutritive food (Hernández, 2012).

Ayerza and Coates (2007) and Fernandez *et al.* (2008) studied the effects of chia seeds feeding on rat plasma. They found that there was significant decrease in serum triglycerides (TG) and low-density lipoprotein (LDL) whereas high-density lipoprotein (HDL) and ω -3 PUFA levels were increased. Sargi *et al.* (2013) endorsed that chia seeds are a source of dietary fiber. They mentioned that eating chia seeds can reduce postprandial blood glucose, systolic blood pressure and inflammation, and increases α -linolenic acid and plasma concentrations of eicosapentaenoic acid. Because, chia seeds can absorb up to 30 times its weight when placed in water, it produces thick mucilage. This soluble fiber cleans the intestines by binding and transporting debris from the intestinal walls so that it can be eliminated efficiently and regularly. A daily dose of chia seed provides an excellent fiber source and most people notice a difference in less than a week (Hernández, 2012).

This study was carried out to improve the physicochemical and quality characteristics of chicken sausage and increase the palatability and product acceptance by consumers, in addition to improve the fatty acid profile by partial substitution of the chicken meat with whole chia seed powder.

MATERIALS AND METHODS

Materials:

Fresh poultry meat (without skin) was purchased from the Assuit local market. Chia seeds were obtained from local market; species mix and salt were purchased from Nasr city, Cairo Governorate, Egypt. Sheep

intestine obtained from a butcher shop in Heliopolis, Cairo Governorate, Egypt.

Chemicals:

All chemicals used in this investigation were obtained from EL-Gomhouria for Trading Chemicals and Drugs Co., Assiut Governorate, Egypt.

Methods:

Preparation of ingredients:

Chicken meat was washed carefully, and then minced with (HR2727 Philips meat mincer, China), using (disc 5 mm). Chia seeds were finally grounded, then every formula proportion of the seeds was weighed after that allowed to swell in 100 ml tap water using to produce the mucilage, in order to make the mixture smooth so that facilitate it's filling. When the chia seed was hydrated, the mucilage was exudate and spiral filaments (mucilage fibers) become apparent. These filaments begin to expand until fully stretched to achieve maximum hydration after 2 h and new structures on seed surface became apparent (Hernández, 2012).

For the preparation of the chicken sausages, the procedures described by Al-Bachir and Othman (2013) with some modification were taken into consideration (Table 1). Minced chicken meat transported to the mixing machine (a Kenwood Mayor Classic KM800 with a K-beater, UK) to receive the remaining ingredients, and mixed to obtain a bind. The treatments were as follows:

Control – without the addition of WCSP (0%);

Treatment 1 – addition of 2% whole chia seed powder (WCSP) (2%, F1);

Treatment 2 – addition of 4% WCSP (4% CE, F2);

Treatment 3 – addition of 6% WCSP (6% CE, F3).

The meat mixtures were packed mechanically into sheep intestine casings (after washing them very well with running tap water to get rid of the salt) then packed in polyethylene bags in foam dish (Fig 1) and stored immediately in a refrigerator at $4\pm 1^{\circ}\text{C}$ until analyses. Other samples were grilled in a small quantity of sunflower oil for 2-3 min with flipping and used for sensory evaluation.

Table (1): Formulation of Chicken sausage

Ingredients	Quantity (%)			
	Control	F1	F2	F3
Minced chicken meat	95.6	93.6	91.6	89.6
Whole chia seed powder (WCSP)	-	2	4	6
Non meat ingredients (spices mix)	3.4	3.4	3.4	3.4
Table salt	1	1	1	1

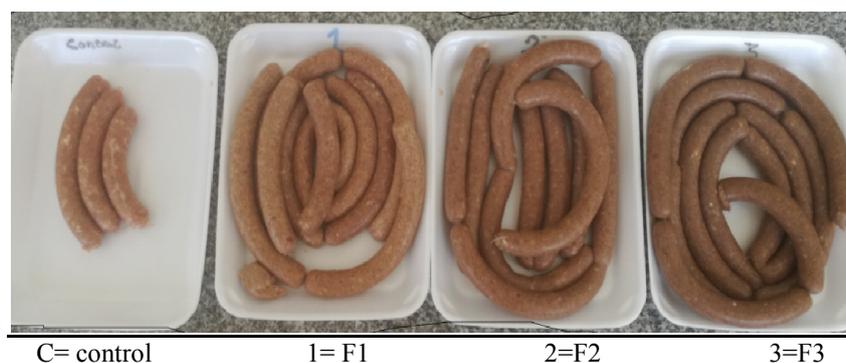


Figure (1): The resultant chicken sausages

Sensory evaluations:

Chicken sausage samples were put in a tray then grilled using hotplate (Mienta HP41325A Duetto Hotplate, China- at 120°C for 2-3 min) until the color turn to golden yellow, then evaluated organoleptically. Grilled chicken sausage samples were evaluated by 10 staff members in the Food Science and Technology Department, Faculty of Agriculture, Assuit University and who are familiar with these products. A 9 point hedonic scale (where 1 corresponding to dislike extremely to 9 represents highly liked) were used to evaluate the sensory attributes of color, taste, flavor, texture and overall acceptability of the prepared chicken

sausage sample according to Gelman and Benjamin (1989).

Water holding capacity (WHC):

Water holding capacity (WHC) was determined according to Sharoba (2009). 0.5 g of sample was placed in circular filter papers, and these between two glass plates, on which a 5 kg weight was placed for 5 min. This variable was then calculated as the weight difference (initial– final).

Cooking loss:

Cooking loss was determined according to Lee et al. (2008). It was measured after grilling chicken sausage samples. Cooking loss was calculated as follows:

$$\% \text{ cooking loss} = \frac{\text{Raw sample weight} - \text{cooked sample weight}}{\text{Raw sample weight}} \times 100$$

Cooking yield:

Cooking yield was calculated as given by (El-Nemr, 1979).

$$\% \text{ Cooking yield} = 100 - \% \text{ Cooking loss}$$

Shrinkage:

The shrinkage percentage was calculated as described by George and Berry (2000) using the following equations: % Shrinkage = (Uncooked diameter or length (cm) - Cooked diameter or length (cm) × 100) / Uncooked diameter or length (cm)

Chemical composition:

Moisture, crude protein, crude fat and ash contents were determined for the prepared chicken sausages according to Official Methods (AOAC, 2005).

Fatty acids composition:

Preparation of methyl ester of fatty acids: The methyl esters of fatty acids were prepared from aliquots of total lipids using 5 ml 3% H₂SO₄ in absolute methanol and 2 ml benzene as mentioned by (Rossell *et al.*, 1983). The contents were heated for methanolysis at 90°C for 90 min and after cooling, phase separation was performed by addition of 2 ml distilled water and methyl ester were extracted with 2 ml aliquots of 5 ml hexane each. The organic phase was removed, filtered through anhydrous sodium sulfate and then concentrated by using rotary evaporator.

Gas liquid chromatography of methyl esters of fatty acids:

The methyl esters of fatty acids were separated using a PYE Unicam Pro-GC gas liquid chromatography with dual flame ionization, and were carried out on (1.5m x 4mm) SP-2310 column, packed with 55% cyan propyl phenyl silicone dimensions. Column temperature: At first the temperature was programmed by increasing the temperature from 70-190°C at the rate of 8°C/min, then isothermal for 10 min at 190°C. The injector and detector temperatures were 250°C and 300°C, respectively. Carrier gas: nitrogen at the rate 30 ml/min. Hydrogen flow rate 33 ml/min and air flow rate 330 ml/min. The chart speed was 0.4 cm/min. Peak identifications were established by comparing the retention times obtained with standard methyl esters. The areas under the chromatographic peak were measured with electronic integrator.

Physical methods

pH value: Ten grams of minced meat sample blended with 90 ml distilled water were measured with a standard combined electrode attached to a digital pH meter (ICM 41150, USA) as described by Varelziz *et al.* (1997).

Statistical analysis

The obtained data from triplicates were analyzed by ANOVA using the SPSS statistical package program (ver. 20), and differences among the means were compared using the Duncan's Multiple Range test (SPSS, 2011). A significance level of 0.05 was chosen.

RESULTS AND DISCUSSION

Sensory evaluation:

According to the means given by the panelists of grilled samples after preparation immediately, sensory scores for studied parameters such as taste, texture, odor, color and general acceptability were presented in Table (2). Results revealed that there were no significant differences in general acceptability, texture, odor, taste and color between the control sample, F1 and F2, but it worth mentioning that adding 2% WCSP to the formula improved the texture than control sample. This can be explained easily because of the significant content of dietary fiber in chia seeds which have high ability of absorbing water, can perform thick mucilage which can retain water and improve the

texture to become juicy. The texture score declined with the increase of WCSP level, this can be explained by two reasons, firstly, beside mentioned previously that chia seeds are absorbing water extensively (30 times its weight), secondly, that we used the same amount of water (100 ml) for the three treatments to produce the mucilage. No significant difference found between F1, F2 and F3 regarding to all parameters except odor, which have been found that F3 differed significantly and had the lowest odor score. The reason referred to the polyphenols content in chia seeds (Oliveira-Alves *et al.*, 2017; Rahman *et al.*, 2017), that may be contributed to the bitterness, astringency, color, flavor, odor and oxidative stability (Pandey and Rizvi, 2009).

Table (2): Effect of adding different levels of WCSP on organoleptic properties of grilled sausage

Chicken sausages	General acceptability	Texture	Odor	Taste	Color
Control	8.72±0.63 ^A	8.09±0.86 ^{ABC}	8.63±0.62 ^A	8.39±0.80 ^{AB}	8.83±0.55 ^A
F1	8.47±0.50 ^{AB}	8.75±0.66 ^A	8.47±0.81 ^A	8.47±0.56 ^{AB}	8.19±0.75 ^{AB}
F2	8.41±0.69 ^{AB}	8.58±0.83 ^{AB}	8.41±0.76 ^A	8.63±0.74 ^A	8.31±0.87 ^{AB}
F3	8.00±0.75 ^{BC}	7.97±1.12 ^{BC}	7.78±1.02 ^B	7.97±0.81 ^{BC}	7.86±1.07 ^{BC}

F1= Chicken sausage with WCSP 2% replacement of chicken meat

F2= Chicken sausage with WCSP 4% replacement of Chicken meat

F3= Chicken sausage with WCSP a 6% replacement of Chicken meat

Different letters in the same column means significantly differences ($p < 0.05$)

Finally, all treatments are acceptable in general, and there are no significant differences between the control and the following two treatments (F1 and F2).

Proximate chemical composition

Results of proximate chemical composition of different chicken sausage samples prepared by the substitution of 2%, 4% and 6% of WCSP are shown in Table (3). It could be noticed that there was significant decrease in moisture content of prepared chicken sausage samples when compared to control as a result of incorporation of WCSP with different levels. The moisture content of control chicken sausage sample was 64.50% as compared with 63.24, 62.57 and 61.32% for chicken sausage prepared with addition of 2%, 4% and 6% of WCSP. Similar results reported by Fernández-López *et al.* (2019), who incorporated chia products (seeds, flour and a coproduct from cold-press) in frankfurters, they postulated that, the addition of 3% chia (in any of its presentations: (seeds, flour or coproduct) decreased the moisture content. It's worth mentioning that, they added 15% water during all frankfurter samples preparation included control. The ability of thick chia mucilage on retaining water, may explain the moisture decrease in the treatments by increasing of the added amount of chia seeds. According to Muñoz *et al.* (2012), mucilage appeared to be firmly attached to the seed, making its extraction difficult.

Protein values showed significant differences among all formulae. Control sample scored the highest protein level followed by F1, F2 and F3, respectively due to the % of chia seeds protein (16.6%). Total fat increased significantly by adding ascending ratios of WCSP due to its high content of fat. Marangoni *et al.* (2015) reported that the fat content of poultry meat varied according to the type of cut. They postulated that the inclusion of skin increased the fat value.

Ash content didn't appear significant differences among prepared treatments compared with control sample which didn't effect by the addition of different concentrations of WCSP.

In this study we used WCSP with 16.6 % protein, 30% total fat, 36.7% crude fibers and 4.45% ash. Kadim *et al.* (2005) illustrated that the chemical composition for the whole broiler carcass (mean±SD) calculated based on dry matter basis were as follows: dry matter: 33.41±2.78 (range: 26.41-43.47), protein: 54.04±6.63 (range: 36.20-76.09), fat 35.44±8.34 (range: 7.50-55.03). Holcman *et al.* (2003) reported that, there is a large range for the values of protein and ash in chickens due to some factors affecting the chemical composition of meat like sex, age, feeding, production method, bread and type of meat. They reported that protein ranged from 17.7 to 23.3%, and ash ranged from 0.7 to 3.63%.

Table (3): Chemical composition of chicken sausage formulated with different levels of WCSP (wet weight) at zero time

Formula	Moisture	Protein	Fat	Ash
Control	64.50 ^a	21.21 ^a	5.77 ^d	1.18 ^a
F1	63.24 ^b	21.11 ^b	6.02 ^c	1.25 ^a
F2	62.57 ^b	21.01 ^c	6.25 ^b	1.32 ^a
F3	61.32 ^c	20.89 ^d	6.51 ^a	1.44 ^a

Different the small letters in the same column means significantly difference ($p < 0.05$) between treatments

Fatty acids profile:

The profile of saturated and unsaturated fatty acids (percentage contribution of each fatty acid to total fatty acids) of the four studied chicken sausage formulae is shown in Table (4).

Data showed that, control sample scored the highest total saturated fatty acids level (35.63%) compared with F1 (33.04%), F2 (27.74%) and F3 (24.68%). Wood *et al.* (2003) reported that meat is a main source of fat in the diet particularly saturated fatty acids. Moreover, saturated fatty acids have a deep

association with diseases related to modern life; especially various cancers and coronary heart disease. Data also showed that substitution of WCSP improved the fatty acids profile which increased the total polyunsaturated fatty acids from 21.38 (control sample) to 29.14, 38.76 and 45.51% (F1, F2 and F3), respectively. Simopoulos (2002) reported that diets which contained large amounts of omega-6s like many processed foods, conventionally raised meat and vegetable or soy-based oils, raise anxious when omega-6s and omega-3s became unbalanced.

Table (4): Fatty acids composition of chicken sausage formulated with different levels of WCSP

Fatty acids	Structure	Control	WCSP		
			2%	4%	6%
Myristic acid	C _{14:0}	2.04	1.73	1.22	0.90
Pentadecylic acid	C _{15:0}	0.27	0.23	0.15	0.12
Palmitic acid	C _{16:0}	23.64	21.95	18.89	17.30
Margaric acid	C _{17:0}	0.49	0.38	0.27	0.21
Stearic acid	C _{18:0}	9.01	8.08	6.94	6.04
Arachidic acid	C _{20:0}	0.14	0.17	0.21	0.19
Behenic acid	C _{22:0}	0.04	0.50	0.06	0.10
Total of SFA		35.63	33.04	27.74	24.86
Myristoleic acid	C _{14:1}	0.46	0.37	0.25	0.19
Palmitoleic acid	C _{16:1}	4.42	3.90	3.19	2.87
cis-10 heptadecenoic acid	C _{17:1}	0.32	0.23	0.17	0.13
Oleic acid	C _{18:1}	37.12	33.21	29.35	26.04
Gadulic acid	C _{20:1}	0.28	0.36	0.39	0.44
Total of MUFA		42.60	38.07	33.35	29.67
Linoleic acid ω-6	C _{18:2}	19.38	20.44	20.95	22.29
γ-Linolenic acid (GLA) ω-6	C _{18:3n6}	0.14	0.15	0.26	0.23
α-Linolenic acid (ALA) ω-3	C _{18:3n3}	1.71	8.23	17.36	22.85
Stearidonic acid ω-3	C _{18:4}	0.14	0.33	0.19	0.14
Total of PUFA		21.38	29.14	38.76	45.51
ω-3		1.85	8.56	17.55	22.99
ω-6		19.52	20.58	21.21	22.53
(ω-6 : ω-3)		10.55	2.40	1.21	0.98
Total of unknown		0.23	0.19580	0.15	ND
*P/S ratio		0.60	0.88	1.39	1.83

*Poly unsaturated fatty acids: Saturated fatty acids

WCSP: whole chia seed powder

SFA: Saturated fatty acids

MUFA: Mono unsaturated fatty acids

PUFA: Poly unsaturated fatty acids

High levels of omega-6s and a lack in omega-3s have been shown to decrease the immune systems function dramatically. A very high omega-6 to omega-3 ratio led to a dozens of health problems like heart diseases, autoimmune disorders, cancers and inflammation. As mentioned by Enser (2001), the ratio of n-6: n-3 PUFA is an incentive factor causes cancers and coronary heart disease, especially the formation of blood clots leading to a heart attack. The recommendation is for an omega-6 to omega-3 ratio of less than 4. Moreover, Kris-Etherton *et al.* (2000) postulated that, massive omega-6 fatty acids in the diet, saturate the enzymes that desaturate and elongate both n-3 and n-6 fatty acids and prevent conversion of ALA into longer eicosapentaenoic (EPA) and docosahexaenoic acid (DHA) forms. Marcinek and Krejpcio (2017) postulated that, chia seed oil had high content of ω -3 acids which enabled reduction the sharing of ω -6 acids in daily food rations. Accordingly, replacing WCSP led to decreasing the ratio omega-6: omega-3, which makes the product beneficial in terms of health, nutrition and technology.

In this investigation, using WCSP decreased the ω -6: ω -3 ratio from 10.55 in control sample to 2.40, 1.21 and 0.98 in F1, F2 and F3, respectively by adding different level of WCSP which contained high content of α -linolenic fatty acid up to 67.8% (Ayerza, 2011).

pH value:

It has been known that, there is a strong relation between pH value and many parameters related to the quality of meat, like color, texture, juiciness, odor, WHC and taste. Table (5) showed that the effect of different concentrations of WCSP on pH values in chicken sausages stored at $4\pm 1^\circ\text{C}$ for 21 days.

Data in Table (5) declared that, there were no significant differences at zero time among treatments by the meaning of that the WCSP doesn't affect the pH values in fresh formulae significantly. This agreed with Scapin *et al.* (2015) and Zaki (2018). All pH values declined significantly during 21 days of storage at $4\pm 1^\circ\text{C}$. This could be explained as mentioned by Wang *et al.* (2013) and Jayawardana *et al.* (2015), who observed that the decrease occurred in pH values due to the growth of lactic acid bacteria which caused the accumulation of lactic acid which reduced pH values. Another reason explained the pH values decrease, is lipid oxidation, as polyunsaturated fatty acids are oxidized by reactive oxygen species leading to a series of secondary reactions which in turn led to lipids degradation as declared by Min and Ahn (2005) and Amaral *et al.* (2018).

Table (5): Changes of pH values of chicken sausage formulated with different levels of WCSP during storage at $4\pm 1^\circ\text{C}$

Sample Storage time	Control	F1	F2	F3
0 days	6.30 ^{aA}	6.48 ^{aA}	6.41 ^{aA}	6.54 ^{aA}
7 days	5.88 ^{cB}	6.10 ^{bB}	6.18 ^{bAB}	6.33 ^{aB}
14 days	-	5.90 ^{bBC}	6.01 ^{abBC}	6.20 ^{aBC}
21 days	-	5.72 ^{bC}	5.85 ^{abC}	6.09 ^{aC}

Different the capital letters in the same columns means significantly difference ($p < 0.05$) between storage periods
Different the small letters in the same row means significantly difference ($p < 0.05$) between treatments

All treatments formulated with WCSP scored higher pH values significantly compared with control sample during 7 days of refrigerated storage, furthermore it has been noticed that the more WCSP % the lower pH reduction whereas F3 recorded the highest pH values during whole storage period than others. Similarly, F2, which didn't appear significant difference compared to F3 after 14 and 21 days of storage. This could be explained by the affect of chia seeds antioxidant content which known to be rich in antioxidants (Reyes-Caudillo *et al.*, 2008) thus could control the polyunsaturated fatty acids oxidation and lipids degradation.

As for lactic acid bacteria which could have a role in decreasing pH values as mentioned above, many studies reported that, chia seeds have antimicrobial activities (Divyapriya *et al.*, 2016). Moreover Elshafie *et al.* (2018) declared that chia seeds essential fatty acids exhibited antimicrobial effect against some

phytopathogenic fungi. Also, Zaki (2018) measured the total bacterial count and psychrotrophic bacteria of camel burger formulated with different levels of chia seeds; he found significant decrease in burgers formulated with chia seeds during 9 and 12 days of storage. Hence, there is a possibility that chia seeds may affect the growth and activity of lactic acid bacteria, so that increasing in pH values in treatments when compared to control.

Water holding capacity (WHC):

WHC is an essential quality parameter for both industry and the consumer. It is affecting tenderness which has been one of the most characteristics that assess the satisfaction of the consumer eating meat (Saelin *et al.*, 2017).

Effect of storage at $4\pm 1^\circ\text{C}$ up to 21 days on WHC expressed as an expressible water (EW) of the studied chicken sausages are shown in Table (6).

Data showed at “zero time” that, there were significant difference between control sample which scored the highest level of EW therefore the least WHC, and the three formulae containing different levels of WCSP which scored less EW subsequently high WHC compared with control sample due to the high fiber content of WCSP. The fibers present in chia have high viscosity leading to gel formation and this can explain the capability of the three formulae F1, F2

and F3 of binding water thus high water holding capacity. Suri *et al.* (2016) mentioned that the insoluble dietary fiber of WCSP can retain water several times of its weight during hydration and thus provides bulk lasts for a long time in the guts. When WCSP are applied in water, they form a slimy material because of its water-soluble fiber which responsible for gel formation. Moreover, chia gel used as a thickening or emulsifying agent in food products (Campos *et al.*, 2016).

Table (6): Changes of WHC (expressed as % Expressible Water) of chicken sausage formulated with different levels of WCSP during storage at 4±1°C

Storage period	Control	F1	F2	F3
0 days	24.53 ^{aB}	18.70 ^{bD}	18.30 ^{cD}	17.73 ^{dD}
7 days	34.13 ^{aA}	22.03 ^{bC}	21.39 ^{cC}	20.70 ^{dC}
14 days	-	22.73 ^{aB}	26.83 ^{bB}	25.37 ^{cB}
21 days	-	29.98 ^{aA}	28.82 ^{bA}	26.74 ^{cA}

Different the capital letters in the same columns means significantly difference ($p < 0.05$) between storage periods

Different the small letters in the same row means significantly difference ($p < 0.05$) between storage treatments

After 7 days of storage at 4±1°C there was a significant increase in EW in control sample from (24.53 to 34.13%). This could be explained by referring to pH value for the control sample which declined from 6.30 to 5.88 during the first week of storage, this significant rapid reduction in ultimate or near ultimate pH resulting in proteins denaturation, including those involved in binding water, thus decreasing in water holding capacity (Deng *et al.*, 2002). There were significant differences among the three treatments formulated with WCSP and control sample at 7 days of storage. Control sample scored the highest level of EW followed by F1, F2 and F3, respectively, by the meaning of the more WCSP% the less expressible water. Among every formula separately, WHC reduced significantly by increasing the storage period. 6% WCSP was superior among all formulae in WHC thus retaining water.

Cooking losses, Cooking Yield and Shrinkage:

Changes of cooking losses, cooking yield and shrinkage of chicken sausage substituted with different levels of WCSP during storage at 4±1°C are shown in Table (7).

Cooking loss was highly affected along the storage period among all studied formulae. This observation is similar to what was reported by Mbagha *et al.* (2014), who noted that aging time affected cooking loss highly. Adding different levels of chia seeds to the three studied formulae improved the cooking loss significantly than control sample which scored the highest levels of cooking loss along storage period. Mushi *et al.* (2009) and Safari (2010) reported that cooking loss in meats depend on ultimate pH, intramuscular fat content. At this point of view, breast had less intramuscular fat, but lower pH, thus, less tenderness with highest cooking loss which means lower WHC. On the other hand, sausages formulated

with WCSP showed less cooking loss which improved with increasing WCSP percentage, thus F3 showed the less cooking loss values along chilling time at 4±1°C because it contained the highest added percentage of WCSP and thus maintained a greater amount of water and is less affected by cooking processes.

Cooking yield is a normal reflection to cooking loss. Data in Table (7) revealed that among all formulae including control sample, cooking yield decreased significantly by increasing storage period, the decreasing was superior in control sample while improved by increasing WCSP ratio among the rest formulae. According to data presented in Table (7), shrinkage data observed significant increase in each formula separately along the chilling period (aging). There are significant differences between control sample and the studied formulae whereas control sample scored the highest shrinkage levels at zero time and 7 days of storage followed by F1, F2 and F3, respectively.

For each storage time, the higher the WCSP ratio, shrinkage levels decreased significantly which assured that WCSP improving the physicochemical characteristics. For each individual formula, shrinkage was increasing significantly by the progress of the storage period but it worth mentioning that shrinkage values during 0 time and 7 days of storage didn't differ significantly, more over there weren't significant differences during storage period at 14 and 21 days for F1, F2 and F3. This could be explained with considering that purge loss, cooking loss, values decreased with increasing pH during ageing (Li *et al.*, 2014), while low pH gave a clear stimulation of protein degradation rate (Pickering *et al.*, 2003), thus according to the results in Table (5), the treatments with WCSP scored higher pH values significantly compared with control thus lower cooking loss and shrinkage values.

Table (7): Changes of Cooking Losses, Cooking Yield and Shrinkage of chicken sausage formulated with different levels of WCSP during storage at 4±1°C

Sample		Control	F1	F2	F3
Storage period (Days)		%			
Zero	Cooking loss	19.18 ^{aB}	17.09 ^{bD}	15.95 ^{cD}	14.25 ^{dD}
	Cooking yield	80.82 ^{dA}	82.91 ^{cA}	84.05 ^{bA}	85.75 ^{aA}
	Shrinkage	7.89 ^{aB}	6.25 ^{bD}	4.24 ^{cD}	3.08 ^{dD}
7	Cooking loss	23.25 ^{aA}	19.39 ^{bC}	16.98 ^{cC}	15.72 ^{dC}
	Cooking yield	76.75 ^{dB}	80.61 ^{cB}	83.02 ^{bB}	84.28 ^{aB}
	Shrinkage	10.16 ^{aA}	8.00 ^{bC}	5.88 ^{cC}	4.38 ^{dC}
14	Cooking loss		22.31 ^{aB}	18.99 ^{bB}	17.62 ^{cB}
	Cooking yield	spoiled	77.69 ^{cC}	81.01 ^{bC}	82.38 ^{aC}
	Shrinkage		11.64 ^{aB}	8.52 ^{bB}	6.29 ^{cB}
21	Cooking loss		24.54 ^{aA}	20.18 ^{bA}	18.59 ^{cA}
	Cooking yield	spoiled	75.46 ^{cD}	97.82 ^{bD}	81.41 ^{aD}
	Shrinkage		13.43 ^{aA}	9.87 ^{bA}	8.28 ^{cA}

Different the capital letters in the same columns means significantly difference ($p < 0.05$) between storage periods

Different the small letters in the same row means significantly difference ($p < 0.05$) between storage treatments

CONCLUSION

It is concluded that the inclusion of WCSP in chicken sausage improved texture, odor and taste, developed the fatty acids profile which increased the total poly unsaturated fatty acids, reduced the omega-6 to omega-3 ratio, decreased the cooking loss and shrinkage percentages while increased the cooking yield percent and WHC. Moreover, adding WCSP raised ash content and declined pH values which reduced the incidence of protein degradation so that getting tenderness and much better texture by retaining water.

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خصائص الجودة لسجق الدجاج المدعم ببذور الشيا

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الهدف من هذا البحث هو تحسين الخصائص الكيموفيزيائية والحسية لسجق الدجاج المدعم عن طريق الاستبدال الجزئي للحم الدجاج الكامل بمسحوق بذور الشيا الكاملة بتركيزات 0 و 2 و 4 و 6٪. تم تقييم السجق الناتج من حيث التركيب الكيميائي، تركيب الأحماض الدهنية، قيمة رقم الأس الأيدروجيني، الخصائص الحسية (الطعم، القوام، الرائحة، اللون والقابلية العامة)، القدرة على الاحتفاظ بالماء، الفقد نتيجة الطهي، المتبقي بعد الطهي، والانكماش أثناء الحفظ بالتبريد على درجة حرارة 4 درجات مئوية ± 1 لمدة 21 يوم. أدى إضافة نسب مختلفة من مسحوق بذور الشيا الكاملة في تحضير السجق إلى تحسين صورة الأحماض الدهنية حيث ارتفعت نسبة الأحماض الدهنية الغير مشبعة الكلية وانخفضت نسبة أوميغا 6 إلى أوميغا 3. كما أدى إلى تحسين القوام والرائحة والطعم، و انخفضت كل من نسبة الفاقد نتيجة الطهي، والانكماش وارتفعت كلا من نسبة الناتج بعد الطهي والقدرة على الاحتفاظ بالماء. أظهرت عينة الكنترول أقل قيمة لرقم الأس الأيدروجيني مقارنة بالثلاث معاملات المضاف إليها بذور الشيا. انخفضت جميع قيم رقم الأس الأيدروجيني بشكل ملحوظ خلال 21 من التخزين بالتبريد على درجة حرارة 4 درجات مئوية ± 1. كانت جميع خلطات سجق الدجاج مقبولة. لم توجد فروق معنوية في الخواص الحسية بين كلا من المعاملتين المحتويتين على نسبة 2%، 4% دقيق بذور الشيا الكامل بينما وجدت اختلافات نوعية مع المعاملة المحتوية على 6% دقيق بذور الشيا الكامل.