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Effect of Fortification with Sesame Protein Isolate, Vitamin C and Calcium Carbonate on Drying Kinetics, Nutritional and Quality Properties of Guava and Strawberry Fruit Bars

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ABSTRACT

Sesame protein isolate, vitamin C and calcium carbonate were used as nutritive ingredients in the production of healthy nutritious fruit bars (guava and strawberry). Drying kinetics of control and fortified fruit bars were investigated. The produced fruit bars were also evaluated for their nutritional, physical and sensory characteristics. The results showed that, the drying rates were higher at the beginning and decreased later with decreasing moisture content and increasing drying time. The drying time required to reduce the moisture content from 82.52 and 82.47% to 16.29 and 19.66% was 5.30 hours for the control and fortified guava fruit bars, respectively, whereas, the drying time required to reduce the moisture content of the control and fortified strawberry fruit bars from 91.72 and 91.63% to 9.49 and 11.62% was 7.30 hours, respectively. There were no remarkable changes in energy values, crude fat, ash and fiber contents, while, the nitrogen free extracts (NFE) were slightly decreased. On the other hand, an apparent increase in protein content and vitamin C was observed in the fortified fruit bars compared with the control ones. The values of acidity, total anthocyanin and total phenols were slightly decreased, while, the pH values were slightly increased as a result of fortification process. All fruit bars revealed optimum color values and good quality attributes. As a conclusion, the fortified fruit bars had acceptable quality attributes and improved nutritional value as compared to control fruit bars.

Keywords: Drying, fortification, fruit bars, nutritional, quality

INTRODUCTION

Fruit bar is a confectionery product with longer shelf life, prepared by drying fruit pulp after mixing with appropriate quantities of sugar, pectin, acid and color. It is also called fruit slabs or fruit leather. Most of fruit bars are classified as intermediate moisture foods as they have moisture content values between 8 and 15%. Fruit bars have a greater nutritional value than the fresh fruits because all the nutrients are concentrated. Several types of fruit bars are developed using different fruits, singly or in combination, including apricot, guava, banana, papaya, mango, sapota, apple, jackfruit, pineapple, grape, date and strawberry. Most of the commercially available fruit bars are synthetic in nature and without fruit pulp. Natural fruit bars are more nutritious and organoleptically acceptable. They contain most of the fruit ingredients and are a rich source of vitamins and minerals and form a good nutritional supplement (Narayana *et al.* 2007; Nadeem *et al*., 2012; Sharma *et al*., 2013; Orrego *et al*., 2014; Kourany *et al*., 2017; Patel and Kulkarni, 2017; Philip and Peter, 2018; Begum *et al*., 2019; Tiwari, 2019; Jabeen *et al*., 2020 and Sree *et al*., 2020).

Guava (*Psidium guajava* L.) is an important fruit crop of the subtropical and tropical regions in the world. It is commercially important because of its flavor and aroma. It has a considerable nutritional importance due to its excellent source of vitamin C, niacin, riboflavin, vitamin A, fibers and minerals. Guava, being a highly perishable fruit, undergoes rapid postharvest ripening in a few days under ambient conditions. It can be consumed fresh or processed into juices, pulps, jams, jellies, dried products or used as an additive to other fruit juices or pulps (Bashir and Abu-Goukh, 2003; Cabral *et al*., 2007; Soares *et al*., 2007, Singh and Pal, 2008 and Kuchi *et al*., 2014; Yadav *et al*., 2017 and Anand *et al*., 2020).

Strawberries (*Fragaria ananassa*) are popular fruits grown in Egypt and many other countries. In the Mediterranean diet, strawberries are a common and important fruit because of their high content of essential nutrients and beneficial phytochemicals, which seem to have relevant biological activity in human health. According to their nutrient profile, the strawberries represent a healthy food choice (El-Beltagy *et al*., 2007; Aaby *et al*., 2012; Giampieri *et al*., 2012 and Gündüz, 2016).

Strawberry is one of the most delicate and highly perishable fruits, due to respiration, weight loss and susceptibility to microbial contamination during post-harvest storage and handling. Therefore, it has a rather limited shelf life in a fresh form. Strawberry can be consumed fresh or processed into juice, jam, jelly, dried powder and snack or used as a semi-moist ingredient in prepared foods (Alvarez *et al*., 1995; Moraga *et al*., 2004; Doymaz, 2008; Agnieszka and Andrzej, 2010 and Basu *et al*., 2014).

Sesame (*Sesamum indicum* L.) is one of the most important and oldest oil seed crops known to man. It is a rich source of oils, protein, carbohydrate, minerals as well as natural antioxidants. Sesame plays an important role in human nutrition, medicinal, pharmaceutical, industrial and agricultural uses. It is a reservoir of nutritional components with numerous beneficial effects along with health

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promotion in humans (Morris, 2002; Sabah El Khier *et al*., 2008; Akbar *et al*., 2012; Pathak *et al*., 2014; Gharby *et al*., 2015; Walallawita *et al*., 2016 and Girmay, 2018).

Sesame seed meal is a by-product after oil extraction. The defatted meal is remarkable an important food for its high protein content. Unlike many oilseeds, the defatted flour and protein isolates prepared from dehulled sesame seeds do not contain undesirable pigments or off-flavors. The major protein fraction which constitutes about 65 – 70% of the total proteins has been designated as alpha-globulin. Sesame proteins are unique nutritionally as they are contain adequate amount of essential amino acids such as methionine, cysteine and tryptophan, which are limiting in many other plant proteins. Therefore, sesame protein isolate can be used to enhance the nutritional value of certain foods especially baby and weaning foods as well as bread, biscuit and other traditional foods. Further, sesame proteins have a very high potential for application in food systems based on their specific functional attributes (Zaghloul, 1998; Zaghloul and Prakash, 2002; Anilakumar *et al*., 2010; Ranganayaki *et al*., 2012; Brewer *et al*., 2016; Fasuan *et al*., 2018 and Vemuri *et al*., 2019).

Knowledge of drying kinetics is of unquestionable importance for the development of process models and understanding the mechanisms of moisture removal. It is important in the design, simulation and optimization of drying processes. The drying curve will give information on the time necessary for a product to be dried under certain conditions. Furthermore, it will help to design or to calculate the size of the dryer (Heldman and Hartel, 1997; Ratti, 2001; Senadeera *et al*., 2003; Guine, 2005 and Ramaswamy and Marcotte, 2006).

The main objectives of this investigation were to (1) Improve the storage stability of the highly perishable fruits (guava and strawberry) and adding value to them by turning into dried fruit bars. (2) Evaluate the effect of fortification with sesame protein isolate, vitamin C and calcium carbonate on the drying kinetics, nutritional and quality properties of the produced guava and strawberry fruit bars.

MATERIALS AND METHODS

Materials:

Freshly harvested guava (*Psidium guajava* L.), strawberry (*Fragaria ananassa*) and white sesame seeds (*Sesamum indicum*) were purchased from the local market, El-Minia, Egypt during the season of 2017. All chemicals used in this investigation were of analytical grade and purchased from Sigma and El-Naser pharmaceutical chemicals.

Methods:

Preparation of sesame protein isolate:

Defatting of sesame seeds:

Sesame seeds were coarsely ground in an electric grinder and defatted with n-hexane with constant stirring for 24 hrs at room temperature (~ 25ºC). A ratio of 1:10 (w/v) seeds to solvent was used. The slurry was defatted two more times (using the same seeds to solvent ratio) until the oil content was less than 1%, filtered through Whatman No.1 filter paper and air-dried at 45ºC for 6 hrs to remove any traces of hexane. The dried defatted sesame meal was used for protein extraction (Prakash and Nandi, 1978 and Achouri *et al*., 2012).

Isolation of sesame total protein:

Sesame total protein was extracted from defatted sesame flour by stirring with 0.02 *M* phosphate buffer of pH 7.5 containing 1 *M* sodium chloride (extraction buffer) using a flour to buffer ratio of 1:10 (w/v) as described by Prakash and Nandi (1978). The extract was centrifuged at 6000 rpm for 30 min using Beckman Model J-21C refrigerated centrifuge at 10ºC. The supernatant was passed through Whatman No.1 filter paper and the clear total protein extract was further used for isolation of α-globulin.

Isolation of α-globulin:

The protein α-globulin was isolated according to Prakash and Nandi (1978) and Zaghloul and Prakash (2002). It was precipitated selectively by dilution of total protein extract to 5.5 times with distilled water. The diluted extract was kept for 2 hrs, decanted and then centrifuged at 6000 rpm for 30 min to separate the protein. The precipitated α-globulin (pellet) was suspended in minimum amount of distilled water, dialyzed against distilled water for about 24 hrs with frequent changes of water to remove buffer salts and sodium chloride and then was dried at 50ºC for 1 hr. The obtained protein isolate was stored in airtight containers at 4°C for analysis and use.

Preparation of fruit bars:

The control and fortified fruit bars (guava and strawberry) were prepared using the formula in Table (1) according to Sarojini *et al*. (2009) with slight modification. The processing steps of fruit bars preparation are illustrated in Fig (1).

Table 1. Formulation of control and fortified fruit bars.

Ingredients (g)	Fruit bars	
	Control	Fortified
Fruit puree (guava / strawberry)	100	96
Sesame protein isolate (SPI)	0.0	3.0
Gelatin	0.0	0.1
Citric acid	0.0	0.2
Vitamin C	0.0	0.2
Calcium carbonate	0.0	0.5

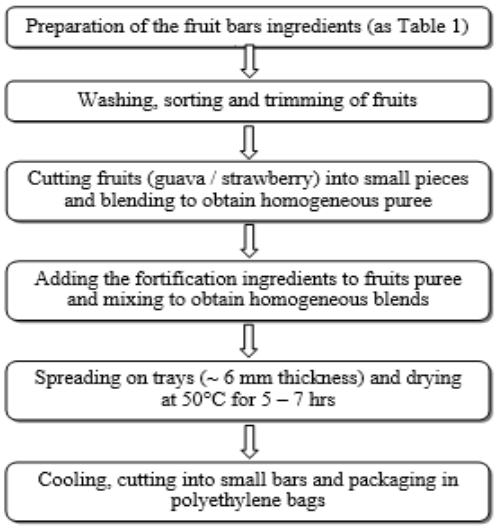

Fig. 1. The processing steps of fruit bars preparation.

Drying kinetics:

Drying curves were obtained by periodic determination of weight and moisture content of samples.

The weight loss from the samples was recorded at certain intervals using an electronic balance with least count of 0.1g. Drying was continued till the sample attained the desired moisture level (equilibrium moisture content). The instantaneous moisture contents at any given time were computed according to Ekechukwu (1999) using the following equation:

$$M_{twb} = 1 - \left[\frac{(1 - M_{owb})\, W_o}{W_t}\right]$$

Where:

M_{twb} = moisture content at time, t (decimal, wet basis); M_{owb} = initial moisture content (decimal, wet basis); W_o = initial weight of fresh product (kg); W_t = weight of product at time, t (kg) and Percentage M_{twb} = M_{twb} x 100.

Chemical analysis:

Moisture, crude protein, crude fat, ash and crude fiber contents were determined according to the methods of the AOAC (2000). Nitrogen free extract (NFE) was calculated by difference. Ascorbic acid was determined by the 2,6-dichlorophenol-indophenol method according to Ranganna (1977). All determinations were performed in triplicates and the means were reported.

Energy values (Kcal/100g):

Energy values were calculated as reported by Greenfield and Southgate (1992) applying the factors, 4, 9 and 4 for each gram of protein, lipids and carbohydrate, respectively.

Determination of pH and titratable acidity:

The pH of samples was determined according to the methods of the AOAC (2000). Titratable acidity (calculated as percent citric acid) was determined according to Adekunte *et al.* (2010).

Determination of total anthocyanins:

Total anthocyanins were determined (as cyanidin-3-glycoside mg/100g) according to Ranganna (1977), using ethanolic HCl as extracting solution and measuring the absorbance at 535 nm.

Determination of total phenols:

Estimation of total phenols was carried out according to Musa *et al.* (2011) using Folin-Ciocalteu reagent. Approximately 10 g sample was homogenized with 100 mL extracting solvent (methanol 50%) for 1 min under high speed. The extracted samples were centrifuged for 15 min at 3000 rpm. The supernatants were collected and passed through Whatman No.1 filter paper. About 0.50 mL sample extract was added with 2 mL distilled water and 2.50 mL diluted Folin-Ciocalteu reagent (0.20 *N*). The samples (extracts with Folin-Ciocalteu reagent) were left for 5 min before 5 mL of 7.5% (w/v) Na_2CO_3 was added. The absorbances were taken at 765 nm after 2 hrs. Calibration curve of gallic acid was set up to estimate the activity capacity of samples. The results were expressed as mg of gallic acid equivalents/100g of sample.

Determination of color:

The color characteristics of samples were measured by a color difference meter (model color Tec-PCM, USA) using different color parameters (L, a, b) according to Francis (1983). In addition, numerical total color difference (ΔE), hue angle and color intensity (chroma) were calculated according to Shih *et al.* (2009) using the following equations:

$$\Delta E = [(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2]^{1/2}$$

$$\text{Hue angle} = [\tan^{-1}(b/a)]$$

$$\text{Chroma} = [(a^2 + b^2)]^{1/2}$$

Where:

L_o, a_o and b_o were the L, a, and b values of the reference sample which here is the control one.

Sensory evaluation:

Sensory evaluation for the color, texture, taste, odor and overall quality were done in order to determine consumer acceptability. A numerical hedonic scale which ranged from 1 to 10 (1 is very bad and 10 for excellent) was used for sensory evaluation (Larmond, 1977).

RESULTS AND DISCUSSION

Drying kinetics of fruit bars:

The drying curves (moisture content versus drying time) for thin layer drying of control and fortified fruit bars are shown in Fig. (2). From which, it could be seen that moisture content decreases continuously with drying time. The drying process was continued until the material achieves its final moisture content at which the moisture content does not decrease substantially with increasing drying time. This final moisture content was considered as the value of equilibrium moisture content (Ekechukwu, 1999; Ramaswamy and Marcotte, 2006 and Sanaa, 2010).

It is obviously observed from the figure that the moisture content is decreased faster at the initial stages of drying and thereafter became slower as drying proceeds. The drying rates were higher at the beginning of the process probably due to the evaporation of moisture from the surface of samples and later decreased with decreasing moisture content. The accelerated drying rates may be attributed to internal heat generation (Pathare and Sharma, 2006; Doymaz, 2007 and Sanaa, 2010).

It is evident from these curves that the drying time required to reduce the moisture contents from the initial moisture contents of 82.52, 82.47, 91.72 and 91.63% to final moisture contents of 16.29, 19.66, 9.49 and 11.62% was about 5.30 hours for the control and fortified guava fruit bars and about 7.30 hours for the control and fortified strawberry fruit bars, respectively.

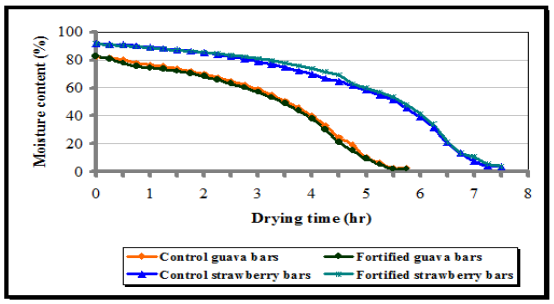

Fig. 2. Drying curves of control and fortified fruit bars.

Chemical composition of raw materials used for fruit bars:

The chemical constituents of raw materials used for fruit bars (sesame protein isolate, guava puree and strawberry puree) are presented in Table (2). From which, it could be seen that the sesame protein isolate contained 95.64, 93.05, 0.62, 2.35, 0.23 and 3.75% dry matter, protein, crude fat, ash, fibers and nitrogen free extract (NFE), respectively. These values were 17.48, 1.54, 3.66, 3.20, 13.34 and 78.26% for guava puree and were 8.28, 8.45, 4.95, 3.38, 8.37 and 74.85% for strawberry puree, respectively.

The data indicated that, sesame protein isolate is a good source of protein. Hence it could be incorporated as nutritive ingredients in the production of healthy fruit bars.

The results in the same table showed that, strawberry puree had a higher content of vitamin C (356.77 mg/100g) than guava puree (281.15 mg/100g). The data indicated that, guava and strawberry are considered as an excellent source of vitamin C. The energy values were 392.78, 352.14 and 377.75 Kcal/100g for sesame protein isolate, guava puree and strawberry puree, respectively. The data in Table (2) are in a good agreement with those reported by Uddin *et al*. (2002); Gandhi and Srivastava (2007); Sanaa (2010); Dattatreya *et al*. (2012); Ali *et al*. (2014); Essa *et al*. (2015); Skrovankova *et al*. (2015); Muzzaffar *et al*. (2016) and Moussa and El-Gendy (2019).

Table 2. Chemical composition of raw materials used for fruit bars (dry weight basis).

Constituents (%)*	Raw materials		
	Sesame protein isolate	Guava puree	Strawberry puree
Dry matter	95.64 ± 0.19	17.48 ± 0.30	8.28 ± 0.20
Protein	93.05 ± 0.13	1.54 ± 0.21	8.45 ± 0.14
Crude fat	0.62 ± 0.06	3.66 ± 0.06	4.95 ± 0.01
Ash	2.35 ± 0.09	3.20 ± 0.02	3.38 ± 0.01
Fibers	0.23 ± 0.04	13.34 ± 0.02	8.37 ± 0.03
NFE **	3.75 ± 0.07	78.26 ± 0.39	74.85 ± 0.61
Vitamin C ***	ND****	281.15 ± 0.86	356.77 ± 0.63
Energy value(Kcal/100g)	392.78	352.14	377.75

*** Means of three determinations ± SD. ** Calculated by difference. *** (mg/100g). ****Not detected.**

Chemical composition of control and fortified fruit bars:

The proximate chemical composition of control and fortified fruit bars (guava and strawberry) are shown in Table (3). From which, it could be seen that control guava fruit bars contained 83.71, 1.58, 3.53, 3.12, 12.13 and 79.64% dry matter, protein, crude fat, ash, fibers and nitrogen free extract (NFE), respectively. The corresponding values for fortified guava fruit bars were 80.34, 5.38, 3.52, 3.46, 11.86 and 75.78%, respectively. The fortified guava fruit bars had a higher content of vitamin C (209.34 mg/100g) than control fruit bars (193.23 mg/100g) and nearly the same energy values (356.65 and 356.32 Kcal/100g).

Table 3. Chemical composition of control and fortified fruit bars (Dry weight basis).

Constituents (%)*	Guava fruit bars		Strawberry fruit bars	
	Control	Fortified	Control	Fortified
Dry Matter	83.71 ± 0.20	80.34 ± 0.21	90.51 ± 0.36	88.38 ± 0.08
Protein	1.58 ± 0.01	5.38 ± 0.03	8.48 ± 0.04	12.15 ± 0.26
Crude fat	3.53 ± 0.01	3.52 ± 0.02	4.81 ± 0.02	4.80 ± 0.10
Ash	3.12 ± 0.22	3.46 ± 0.10	3.21 ± 0.04	4.07 ± 0.10
Fibers	12.13 ± 0.17	11.86 ± 0.01	8.12 ± 0.04	8.11 ± 0.05
NFE **	79.64 ± 0.39	75.78 ± 0.63	75.38 ± 0.50	70.87 ± 0.41
Vitamin C***	193.23 ±0.01	209.34 ±0.29	277.29 ±0.02	294.70 ±0.50
Energy value (Kcal/100g)	356.65	356.32	378.73	375.28

*** Means of three determinations ± SD. ** Calculated by difference. *** (mg/100g).**

The results in Table (3) showed that control strawberry fruit bars contained 90.51, 8.48, 4.81, 3.21, 8.12 and 75.38% dry matter, protein, crude fat, ash, fibers and nitrogen free extract (NFE), respectively. The corresponding values for fortified strawberry fruit bars were 88.38, 12.15, 4.80, 4.07, 8.11 and 70.87%, respectively. The fortified strawberry fruit bars had a higher content of vitamin C (294.70 mg/100g) than control fruit bars (277.29 mg/100g) and nearly the same energy values (378.73 and 375.28 Kcal/100g).

In the light of the obtained results, it could be concluded that there were no remarkable changes in energy values, crude fat, ash and fiber contents, while, the nitrogen free extracts (NFE) were slightly decreased. On the other hand, an apparent increase in protein content and vitamin C was observed in the fortified fruit bars compared with the control ones.

Total phenols, total anthocyanin, pH and titratable acidity values of raw materials used for fruit bars:

Total phenols, total anthocyanin, pH and titratable acidity values of raw materials used for fruit bars (sesame protein isolate, guava puree and strawberry puree) are shown in Table (4). From which, it could be seen that guava puree had a higher content of total phenols (225.40 mg/100g) than strawberry puree (203.38 mg/100g), while not detected in sesame protein isolate. Total anthocyanin was only detected in strawberry puree and found to be 46.7 mg/100g (as cyanidin-3-glycoside). The pH and titratable acidity values were 6.27 and 0.34% (as citric acid) for sesame protein isolate, 4.20 and 0.55% for guava puree, 3.70 and 0.65% for strawberry puree, respectively. The data in Table (4) are in a good agreement with those reported by Chen *et al*. (2007); Marjanovic-Balaban *et al*. (2012); Ornelas-Paz *et al*. (2013); Howard *et al*. (2014); Concha-Meyer *et al*. (2016); Patel *et al*. (2016) and Olasunkanmi *et al*. (2017).

Table 4. Total phenols, total anthocyanin, pH and titratable acidity values of raw materials used for fruit bars.

Parameters*	Raw materials		
	Sesame protein isolate	Guava puree	Strawberry puree
Total phenols**	ND****	225.40 ± 1.23	203.38 ± 0.38
Total anthocyanin**	ND****	ND****	46.7 ± 0.23
pH	6.27 ± 0.03	4.20 ± 0.02	3.70 ± 0.01
Titratable acidity(%)***	0.34 ± 0.04	0.55 ± 0.01	0.65 ± 0.01

*** Means of three determinations ± SD. ** (mg/100g). *** (as % citric acid). ****Not detected.**

Total phenols, total anthocyanin, pH and titratable acidity values of control and fortified fruit bars:

Total phenols, total anthocyanin, pH and titratable acidity values of control and fortified fruit bars are shown in Table (5). The results showed that total phenols were slightly decreased from 205.68 to 199.15 mg/100g (as gallic acid) for control and fortified guava fruit bars and from 180.39 to 175.28 mg/100g for control and fortified strawberry fruit bars, respectively as a result of fortification with sesame protein isolate. Total anthocyanin followed the similar pattern as total phenols. It was slightly decreased from 61.15 to 57.97 mg/100g (as cyanidin-3-glycoside) for control and fortified strawberry fruit bars, respectively. The pH values were slightly increased from 4.74 to 4.77 for control and fortified guava fruit bars and from 3.22 to 3.51 mg/100g for control and fortified strawberry fruit bars, respectively. Titratable acidity values were decreased from 0.16 to 0.12% for control and fortified guava fruit bars and from 0.84 to 0.48% for control and fortified strawberry fruit bars, respectively. The results are in accordance with those reported by Concha-Meyer *et al*. (2016) for strawberry and kiwi leathers; Kourany *et al*. (2017) for mango and guava fruit bars; Begum *et al*. (2019) for guava fruit bar and Srivastava *et al*. (2019) for guava-orange fruit bar.

Table 5. Total phenols, total anthocyanin, pH and titratable acidity values of control and fortified fruit bars.

Parameters*	Guava fruit bars		Strawberry fruit bars	
	Control	Fortified	Control	Fortified
Total phenols**	205.68 ± 0.77	199.15 ± 0.78	180.39 ± 0.96	175.28 ± 0.38
Total anthocyanin**	ND****	ND****	61.15 ± 1.23	57.97 ± 0.77
pH	4.74 ± 0.05	4.77 ± 0.04	3.22 ± 0.01	3.51 ± 0.07
Titratable acidity***	0.16 ± 0.05	0.12 ± 0.04	0.84 ± 0.05	0.48 ± 0.03

*** Means of three determinations ± SD. ** (mg/100g).**
***** (as % citric acid). ****Not detected.**

Color parameters of raw materials used for fruit bars:

The results of color parameters (L, a, b, ΔE, hue angle and chroma) for raw materials used for fruit bars (sesame protein isolate, guava puree and strawberry puree) are presented in Table (6). The results showed that the color parameters L, a, b, ΔE, hue angle and chroma for sesame protein isolate were 75.00, 12.52, 14.54, 00.00, 49.24 and 19.18, while were 65.33, 3.46, 23.98, 00.00, 81.79 and 24.22 for guava puree and were 31.66, 27.53, 14.09, 00.00, 27.10 and 30.93 for strawberry puree, respectively. The data in Table (6) are in a good agreement with those reported by Sanaa (2010) for fresh guava and strawberry fruits.

Table 6. Color parameters of raw materials used for fruit bars.

Color parameters*	Raw materials		
	Sesame protein isolate	Guava puree	Strawberry puree
L (Lightness)	75.00 ± 0.20	65.33 ± 2.51	31.66 ± 3.45
a (redness/greenness)	12.52 ± 0.84	3.46 ± 0.97	27.53 ± 1.89
b (yellowness/blueness)	14.54 ± 1.36	23.98 ± 1.34	14.09 ± 2.17
ΔE**	00.00	00.00	00.00
Hue angle***	49.24	81.79	27.10
Chroma****	19.18	24.22	30.93

***Means of three determinations ± SD.**
****$\Delta E = [(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2]^{1/2}$**
***** Hue angle = $[\tan^{-1}(b/a)]$. **** Chroma = $[(a^2 + b^2)]^{1/2}$**

Color parameters of control and fortified fruit bars:

The Hunter color parameters (L), (a) and (b) are widely used to describe color changes of food materials. However, it is recommended to use hue angle and chroma as more practical measures of color. The color changes can also be expressed as a single numerical value ΔE. This value defines the magnitude of the total color difference. Preferred colors are those closest to the original color of samples (McGuire, 1992; Albanese *et al*., 2007 and Shih *et al*., 2009).

The results of color parameters (L, a, b, ΔE, hue angle and chroma) for control and fortified fruit bars are given in Table (7). From which, it could be seen that control guava fruit bars had the color values of 51.93, 10.75 and 33.59 for lightness (L), redness (a) and yellowness (b), respectively. The corresponding values for fortified guava fruit bars were 49.87, 11.13 and 34.10, respectively. The control strawberry fruit bars had the color values of 21.92, 37.33 and 14.74 for lightness (L), redness (a) and yellowness (b), respectively. The corresponding values for fortified strawberry fruit bars were 21.12, 38.76 and 14.82, respectively. The results indicated that, L-values were slightly decreased, whereas, a-values and b-values slightly increased for all fruit bar samples as compared to the control one. There are slight differences in brightness, redness and yellowness values of all fruit bar samples. Consequently, slight differences in ΔE values were observed (2.16 for guava fruit bars and 1.64 for strawberry fruit bars). Nevertheless, this minute total color difference can not be distinguished by the naked eye in some cases.

It could also be seen that, the control and fortified guava fruit bars had nearly the same values of hue angle (72.25 and 71.92) and chroma values (35.27 and 35.87). The corresponding values for control and fortified strawberry fruit bars were 21.55 and 20.92 for hue angle and 40.13 and 41.50 for chroma. This could be due to the slight change in the values of both redness (a-value) and yellowness (b-value) as a result of the fortification process. It was reported that chroma is the indicator of color saturation and intensity. The higher the values, the more desirable they are (McGuire, 1992; Albanese *et al*., 2007 and Shih *et al*., 2009).

In the light of the obtained results, it could be concluded that there were no much changes in the color characteristics as a result of the fortification process and all fruit bars revealed optimum color values.

Table 7. Color parameters of control and fortified fruit bars.

Color parameters*	Guava fruit bars		Strawberry fruit bars	
	Control	Fortified	Control	Fortified
L (Lightness)	51.93 ± 1.58	49.87 ± 1.43	21.92 ± 0.89	21.12 ± 0.80
a (redness/greenness)	10.75 ± 1.50	11.13 ± 1.09	37.33 ± 1.00	38.76 ± 0.55
b (yellowness/blueness)	33.59 ± 2.20	34.10 ± 1.40	14.74 ± 0.62	14.82 ± 0.80
ΔE**	00.00	2.16	00.00	1.64
Hue angle***	72.25	71.92	21.55	20.92
Chroma****	35.27	35.87	40.13	41.50

***Means of three determinations ± SD.**
****$\Delta E = [(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2]^{1/2}$**
***** Hue angle = $[\tan^{-1}(b/a)]$. **** Chroma = $[(a^2 + b^2)]^{1/2}$**

Sensory characteristics of control and fortified fruit bars:

Sensory evaluation for color, texture, taste, odor and overall quality of control and fortified fruit bars as influenced by the fortification process were done in order to determine consumer acceptability. The results are shown in Fig. (3).

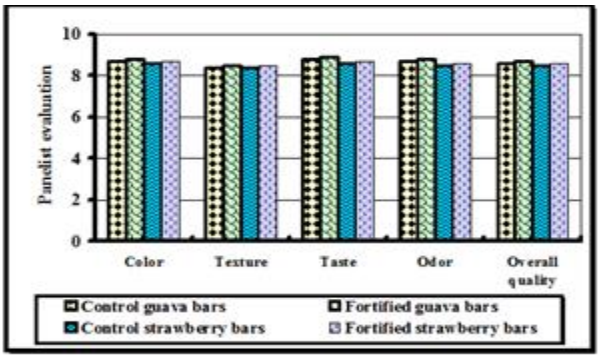

Fig. 3. Sensory characteristics of control and fortified fruit bars.

It could be seen that the control and fortified fruit bars recorded nearly the same sensory quality in terms of color (87 – 88%), texture (84 – 85%), taste (88 – 89%), odor (87 – 88%) and overall quality (86 – 87%) for control and fortified guava fruit bars, respectively. The corresponding values for control and fortified strawberry fruit bars were (86 – 87%), (84 – 85%), (86 – 87%), (85 – 86%) and (85 – 86%), respectively. These data indicated that the fortification

process did not affect the sensory quality of fruit bars and all fortified samples were as good as that of control ones, which revealed optimum quality attributes. The photographs of control and fortified fruit bars are shown in Fig. (4).

Fig. 4. The photographs of control and fortified fruit bars.

CONCLUSION

In the light of the obtained results, it could be concluded that, sesame protein isolate is a good source of protein. Hence it could be incorporated as nutritive ingredients in the production of healthy nutritious fruit bars (guava and strawberry). The fortified fruit bars had acceptable quality attributes and improved nutritional value as compared to control fruit bars.

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تأثير التدعيم بمعزول بروتين السمسم وفيتامين ج وكربونات الكالسيوم على سلوك معدل التجفيف والخواص الغذائية والجودة للفائف الجوافة والفراولة

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تم استخدام معزول بروتين السمسم ، وفيتامين ج وكربونات الكالسيوم كمكونات تدعيم غذائية في إنتاج لفائف الفاكهة المغذية الصحية (الجوافة والفراولة). تم دراسة سلوك معدل التجفيف (منحنيات التجفيف) للفائف الكنترول والمدعمة. كما تم تقييم اللفائف الناتجة من حيث قيمتها الغذائية وخواصها الفيزيائية والحسية. أوضحت النتائج أن المحتوى الرطوبي يتناقص باستمرار مع زمن التجفيف وأن معدل التجفيف كان أسرع في بداية عملية التجفيف ثم انخفض بعد ذلك مع انخفاض المحتوى الرطوبي وزيادة زمن التجفيف. وجد أن زمن التجفيف اللازم لخفض المحتوى الرطوبي من ٨٢,٥٢ ، ٨٢,٧٤% إلى ١٦,٢٩ ، ١٩,٦٦% كان ٥,٣٠ ساعة للفائف الجوافة الكنترول والمدعمة علي الترتيب. في حين أن زمن التجفيف اللازم لخفض المحتوى الرطوبي للفائف الفراولة الكنترول والمدعمة من ٩١,٧٢ ، ٩١,٦٣% إلى ٩,٤٩ ، ١١,٦٢% كان ٧,٣٠ ساعة علي الترتيب. لم تحدث تغيرات ملحوظة في أي من قيم الطاقة ومحتوى الدهن والرماد والألياف ، بينما انخفض محتوى المستخلص الخالي من النيتروجين قليلاً. على الجانب الأخر لوحظت زيادة واضحة في محتوى البروتين وفيتامين ج في اللفائف المدعمة مقارنة بالكنترول. كما أوضحت النتائج حدوث انخفاض طفيف في قيم الحموضة والأنثوسيانين الكلي والفينولات الكلية ، بينما زادت قيم رقم الحموضة (pH) قليلاً نتيجة لعملية التدعيم. أظهرت جميع عينات اللفائف قيم لون مثالية وخصائص جودة جيدة. كنتيجة عامة وفي ضوء النتائج المتحصل عليها يتضح أن لفائف الفاكهة المدعمة كان لها خصائص جودة مقبولة وقيمة غذائية محسنة مقارنة بالكنترول.