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Oxidative stability and quality assurance of chilled beef meatballs using broccoli sprouts

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ABSTRACT

The study was conducted to assess the quality of beef meatballs influenced by adding of fresh broccoli sprouts (BS) at different concentrations (5, 10 and 15%) of total formula of beef meatballs. Antioxidant activity (total phenols, total flavonoid and DPPH) of broccoli sprouts were evaluated and found to contain a higher amount of bioactive compounds. Based on the chemical composition of uncooked meatballs, there were noticeable significance differences ($p < 0.05$) in moisture, protein, ash, and fiber content of beef meatballs incorporated with broccoli sprouts (5% , 10% ,15%) as compared with the control and butylated hydroxyl toluene (BHT) beef meatballs samples. Furthermore, the addition of various concentrations of broccoli sprouts resulted in significantly ($P < 0.05$) lower pH, TBA, cooking loss, and shrinkage percentages, while water holding capacity and cooking yield were improved by time as compared with control and BHT meatball groups over the 12-day storage period. The lipid oxidation in beef meatballs enriched with broccoli sprouts was inhibited and maintain reduced percentage of thiobarbituric acid reactive substances (TBARS) comparable to control along the storage period. Moreover, broccoli sprouts incorporation provides the beef meatballs acceptable sensorial scores without negatively affecting their organoleptic characteristics and overall acceptability parameters. Broccoli sprouts with 15% concentration demonstrated the most potent effective natural antioxidant delaying lipid oxidation, cooking properties and enhance the sensory properties of meatballs compared to the concentrations 5% and 10%. Finally, the results of this research suggest that broccoli sprouts could serve as a safe natural antioxidant source for meat products.

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INTRODUCTION:

Meat products are a vital component of the human diet, and their consumption has risen recently on a global scale. These meals are a reliable source of energy as well as numerous nutrients, including vital amino acids, high biological value proteins , minerals including selenium , zinc, iron as well as manganese, and vitamin B12 **(Ursachi et al. 2020).** Furthermore, a great deal of research has been conducted on meat products due to many factors like the growing population's consuming meat products, consumers' growing health consciousness, and the negative effects of synthetic additives and addressing concerns about their health safety and sometimes quality **(Manzoor and Ahmad 2021).**

Scientists researching the preservation of meat products are primarily focused on oxidative reactions because they can lead to discoloration of meat, which can be rejected by consumers, as well as the production of toxic compounds, aroma, and flavour changes (**Munekata et al. 2020).** According to **Domínguez et al. (2019)** during the undesired lipid oxidation of meat products, additional losses may happen to vitamins, essential fatty acid and essential amino acid. **Zamuz et al. (2018),** reported that processing procedures like grinding of meat can cause an increase in lipid oxidation rates because of the large surface area exposed to oxygen. Previous alterations adversely impact the sensory quality, nutritional content, and consumers acceptance and shortens the shelf life of meat **(Madane et al. 2019)**.

Chemical preservatives as well as physical and biological treatments, or their mixtures, have been used to preserve food and prolong shelf life of food (**Sridhar et al. 2020; Huang. 2021**). Some producers used artificial antioxidants like butylated hydroxyl anisole (BHA) and butylated hydroxyl toluene (BHT) simultaneously such additives cause harm to the consumer health. Customers recently have made claims for meat products with increased nutritional value that may be good for human health. To satisfy these needs, researchers have concentrated on the potential for creating reformulated meat products that include less or no harmful additives, incorporate certain beneficial ingredients, and applying natural antioxidants **(Gagaoua and Picard 2020)**. So, recently the meat sector has expanded due to new methods of processing meat products, Plant sprouts are now viewed as a functional food and have attracted more attention (**Keshri et al. 2019).** An interesting way to increase the nutritional content of the food is to incorporate sprouts as a basic ingredient **(Miyahira et al. 2021).**

Broccoli sprouts are common brassica vegetable with antibacterial, anti-inflammatory, anticancer, and anti-obesity characteristics **(L´opez-Chill´on et al. 2019)**. Broccoli sprouts displayed more than ten times greater glucosinolate contents than mature broccoli ones due to their immature physiological condition following germination of seed **(Baenas et al. 2016).**

Broccoli sprouts are seeds that germinate after 7 to 9 days, and are known to be highly abundant in antioxidants, vitamin C, and phenolic compounds (**Zielinski et al. 2003).** The presence of sulforaphane in broccoli is also notable since It has the ability to strongly stimulate the removal of dangerous toxins that cause cancer (**Zhang and Callaway (2002)).** Besides, there is evidence that broccoli sprouts possess antimicrobial properties against Helicobacter pylori in vitro (**Moon et al. 2010)**. **Talalay et al. (2007**) indicating that applying sulforaphane-containing broccoli sprout extract topically shields both humans and animals against UV radiation.

Broccoli sprouts provide a good source of phenolic acids and flavonoids (**Gawlik-Dziki et al. 2012)**, which serve as natural antioxidants and can help extend the quality and meat stability. As a result, this study intended to assess the oxidative stability and quality characteristics of refrigerated beef meatballs that were formulated to include a specific amount of broccoli sprouts powder.

MATERIAL AND METHODS

Broccoli sprouts extract preparation:

Broccoli sprouts were obtained from (Mnabet Company, 6 October City, Egypt).

The sprouts were subjected to freeze drying using vacuum freeze drier (LABOAO) at Microanalysis Unit, Faculty of Science, Tanta University, Egypt, oven for 48 hours, subsequently, the dehydrated sprouts were ground into a powder using a blender and then sieved before being used. To obtain the extract, 50 ml of distilled water was thoroughly mixed with 2 gm of the powdered plants, and the mixture was allowed to stand for 5 minutes. After that, the mixture was filtered using Whatman grade No.1 filter papers and concentrated in a rotary evaporator (BuchiRotavapor R, Switzerland) at 50°C according to the procedure outlined by **Alaklabi et al. (2017).**

Evaluation of total phenolic, total flavonoid contents and antioxidant activity in broccoli sprouts :

Total phenolic, flavonoid content and antioxidant activity of broccoli sprouts were analyzed at Food Technology Research Institute**,** Kafr-elsheikh branch**.** The total phenolic content of the plant extracts assessed based on **Dewanto et al. (2002).** Data is given as mg of the dried plant's gallic acid equivalent (GAE) per g. Flavonoid content was assessed by most popular spectrophotometric method as reported by **Arvouet-Grand et al. (1994),** which was then represented as quercetin equivalents (mg QE/g DM). Antioxidant activity AA% of extract was assessed according to **Gallego et al. (2015)** The percentage scavenging activity (%) could be calculated according to this equation:

DPPH (% of antioxidant activity) =
[(A (absorbance) **control – A** (absorbance) **sample)/A** (absorbance**) control] x 100= %**

Manufacturing of meatballs:

Minced meat was purchased from a commercial market, Tanta, Egypt. A standard formula was used in the production of meatballs: 85% minced beef (20% fat content),7.5% onion, 1.5% salt, 1% spices and 5 % water. After homogenizing of all ingredients for five minutes in a bowl mixer (Tefal, QA400, France), the ingredients were split into 5 groups. 1st group (control group) (C) without any antioxidant source (broccoli sprouts or BHT) 2nd group (T1) meatballs with 5% broccoli sprouts powder, 3rd group (T2) meatballs with 10% broccoli sprouts powder, 4th group (T3) meatballs with 15% broccoli sprouts powder and 5th group (T4) meatballs with BHT at 0.1% as a reference. Meatballs (30±2 gm) were formed the approximate size of each one was 5 cm in width and 1 cm in thickness, all treatment were examined for sensory analysis to choose the best accepted treatment. Then treatments were arranged into plastic trays, Packaging with single layer of polyethylene bag and kept in refrigerator at 4±1°C for 12 days. Meatballs examination was assessed at 0, 3, 6, 9 and 12 days of storage or until it shows signs of spoilage.

Chemical composition of beef meatballs samples:

Ash, protein, moisture, fat and fiber contents of beef meatballs samples were assessed using **(AOAC. 2000)**.

pH measurement:

To measure the pH values, the technique outlined by **Yetim et al. (2011)** was employed**.** 5gm of beef meatball was mixed with 50 mL of deionized distilled water. Then filtration of the mixture ,using a digital pH meter (Hanna Instruments, Milano, Italy), the filtrate's pH was determined.

Thiobarbituric acid value (TBARS) analysis:

To monitor lipid oxidation , thiobarbituric acid reactive **substances** (TBARS) was assessed based on **Zhang et al. (2016) .** TBARS levels were recorded as mg of malonaldehyde per kg of meatballs .

Water Holding Capacity (WHC):

WHC evaluated based on the process described in El-**Seesy. (2000**). A small piece of meat **weight** 0.3 g was centered on filter paper (Whatman No.1), and inserted between two glass plates (sized 10.0 × 10.0 × 0.8 cm). A weight of one kilogramme was put on the upper plate, and after elapsing of 20 minutes, the area of the meat that had been pressed down and the entire surface area of the wet paper was determined by a digital planometer (QCJ-2000).WHC was determined using the equation that follows:

$$\text{WHC}\,\% = \left(\frac{\text{area of moisture of unpressed meat (mm2)}}{\text{area of moisture of pressed meat (mm2)}}\right) \times 100$$

Determination of Fat retention %:

Fat retention of beef meatballs was calculated as described by **Serdaroğlu and Değırmencioğlu (2004)** following the formula**:**

$$\text{Fat retention}(\%) = \frac{\text{cook weight} \times \text{fat in cook meatball \%}}{\text{Row weight} \times \text{fat in uncook meatball \%}} \times 100$$

Determination of cooking loss (CL):

It was calculated as outlined by **(Erdogdu et al. 2007)** following the formula**:**

$$\text{Cooking Loss (CL \%)} = \frac{\text{Mi} - \text{Mf}}{\text{Mi}} \times 100$$

Where:

M_i = Initial mass of the raw beef meatballs in gram.

M_f = Final mass of the cooked beef meatballs in gram.

Determination of cooking yield:

It was assessed by contrasting the weight of the sample before and after cooking and was determined as described by **Murphy et al. (1975):**

$$\text{Cook yields}(\%) = \frac{\text{Weight of cooked sample}}{\text{Weight of raw sample}} \times 100$$

Determination of Beef meatball shrinkage (%):

Beef meatball shrinkage is the variation between raw and cooked portions of the Beef meatball , represented as described by **Darweash and Moghazy. (1998**) following the equation:

$$\text{Beef meatball shrinkage \%} = \frac{\text{Fresh meat area} - \text{Cooked meat area}}{\text{Fresh meat area}} \times 100$$

Sensory analysis:

The beef meatballs were cooked for three minutes on (a Tefal, Rumilly, France fryer). After that, they were randomly served to 15 panelists, ages 25 to 40 on averages, at a temperature of about 35 °C. Panelists were asked to rate the cooked samples according to parameters related to color, taste, tenderness, juiciness, appearance, and overall acceptability during the sensory evaluation process (**Badr and El-Waseif. 2017).** rated the samples using a ten-point hedonic scale, where 1 represents extreme dislike, 5 represents unacceptable level and 10 represents like very much.

Statistical Analysis:

SPSS (version 22.0, IBM, USA) statistical software was used to evaluate the measurements. The mean ± standard errors (SE) was used to expressed all parametric data, and one-way analysis of variance (ANOVA) was used, subsequently the test for least significant differences (LSD). The groups' mean comparisons became significant when ($p<0.05$).

RESULTS:

As shown in **Table (1)** , the values of phenolic content (TPC), total flavonoid content (TFC) and antioxidant activity by DPPH of broccoli sprouts extracted by methanol had higher significant variations (34.39 milligram of gallic acid equivalents (mg GAE) / g DW, 2.29 milligram of quercetin equivalent (mg QE/g) DW and 64.70 %), than broccoli sprouts extracted by water (32.78mg GAE/g DW, 1.86 mg QE/g DW and 54.83%), respectively

Table 1. Antioxidant characteristics of Broccoli sprouts.

extract solvents	TPC (mg GAE/g DW)	TFC (mg QE /g DW)	DPPH Activity (Inhibition %)
Water	32.78± 0.01 ^{b}	1.86^{b}± 0.01 ^{b}	54.83± 0.4 ^{b}
70% Methanol	34.39^{a}± 0.01 ^{a}	2.29^{a}± 0.05 ^{a}	64.70± 0.06 ^{a}

Values with different superscript litters within the same column are significantly different ($p \leq 0.05$). Values (n=3/ group) are means ± SE (standard error).

The outcomes attained in **table (2)** indicate that protein , ash , moisture and fiber content were notably elevated in the broccoli sprouts (BS) treated meatball samples as compared with control . On the other hand, there is no significant differences (p>0.05) were observed in fat contents of all samples

Table 2. Chemical criteria (%) of control and treated uncooked beef meatball samples:

	Chemical criteria (%)				
Samples	Protein (%)	Ash (%)	Moisture (%)	Fiber (%)	Fat (%)
Control	22.21±0.9c	2.51±0.6d	66.28±0.7c	0.21±0.02d	17.85±0.2a
0.1%BHT	22.99±0.3c	2.61±0.05d	66.81±0.3c	0.27±0.01d	18.58±0.2a
5% Broccoli sprouts	25.49±0.2b	4.61±0.6c	67.80±0.6bc	4.38±0.1c	18.46±0.3a
10% Broccoli sprouts	26.33±0.4ab	5.76±0.2b	68.86±0.07b	6.61±0.1b	18.43±0.1a
15% Broccoli sprouts	27.88±0.2a	6.27±0.3a	71.34±0.4a	8.38±0.2a	18.44±0.06a

Values with different superscript within the same column are significantly different ($p \leq 0.05$)

The changes in pH values of the control beef meatballs, (0.1%) BHT and meatballs prepared with (5%, 10%,15%) broccoli sprouts groups are presented in **table (3).** At zero time the pH of the control, (0.1%) BHT and 5%, 10%, 15% broccoli sprouts beef meatballs groups were 5.44 ± 0.01, 5.41 ± 0.01, 5.43±0.03 , 5.47±0.03 and 5.46 ± 0.04, respectively. At the end of storage period, mean pH values were 6.30±0.1, 5.60±0.01, 5.78±0.01, 5.76±0.02 and 5.68 ±0.01 in control , (0.1%) BHT , 5% , 10% and 15% broccoli sprouts groups, respectively. Compared to control group, all (0.1%) BHT and broccoli sprouts treated groups at 6, 9, 12 days from storage period exhibited significantly lower pH values (p<0.05).

Table 3. Mean pH values in control and formulated beef meatballs .

Samples	pH				
	0 day	3^{th} day	6^{th} day	9^{th} day	12^{th} day
Control	5.44±0.01a	5.56±0.01a	5.80±0.05a	6.00±0.01a	6.30±0.1a
0.1% BHT	5.41±0.01a	5.46±0.02b	5.52±0.03b	5.61±0.01c	5.60±0.01c
5% Broccoli sprouts	5.43±0.03a	5.47±0.04ab	5.63±0.06b	5.68±0.01b	5.78±0.01b
10% Broccoli sprouts	5.47±0.03a	5.49±0.03ab	5.51±0.03b	5.62±0.02c	5.76±0.02b
15% Broccoli sprouts	5.46±0.04a	5.45±0.02b	5.56±0.02b	5.62±0.01c	5.68±0.01b

Values with different superscript within the same column are significantly different ($p \leq 0.05$)

Table (4) clarified that, At zero day, there were no significance difference in TBARs values ($P > 0.05$) between control and treated groups then from 3^{th} day the (0.1%) BHT meatballs group and meatballs enriched with (5%, 10% and 15%) broccoli sprouts groups had significantly($P \leq 0.05$) lower TBA than control one. At 6^{th} day of storage, meatballs enriched with (5%, 10%, 15%) broccoli sprouts has TBA value (0.72±0.5, 0.60±0.3 and 0.55±0.1 mg MA/ kg) respectively, which still remained the TBA acceptability limit of **ES (1694/2005)** (0.9 mg MDA/kg) while the control group were unaccepted (0.96±0.1) mg MDA/kg. On the 12th day of storage, the control group exhibited the highest value at 1.94±0.1 mg MDA/kg, while the 15% BS group showed the lowest value at 0.84±0.1 mg MDA/kg.

Table 4. Mean TBA values (mg MDA/kg) of control and treated beef meatballs .

Samples	TBA (mg MDA/kg)				
	0 day	3^{th} day	6^{th} day	9^{th} day	12^{th} day
Control	0.35±0.1a	0.63±0.1a	0.96±0.1a	1.38±0.1a	1.94±0.1a
0.1% BHT	0.35±0.1a	0.44±0.1b	0.54±0.1c	0.68±0.1d	0.75±0.4d
5% Broccoli sprouts	0.35±0.1a	0.52±0.2b	0.72±0.5b	0.91±0.4bc	1.07±0.2bc
10% Broccoli sprouts	0.35±0.1a	0.46±0.1b	0.60±0.3c	0.85±0.1b	0.97±0.3b
15% Broccoli sprouts	0.35±0.1a	0.43±0.1b	0.55±0.1c	0.78±0.1cd	0.84±0.1cd

Values with different superscript within the same column are significantly different ($p \leq 0.05$)

The water holding capacity of the produced uncooked beef meatballs samples during storage times at 4 °C for 12 days was assessed and recorded in **table (5)**. At zero day, the uncooked beef meatballs samples did not differ significantly (p>0.05) in WHC but through the 12 days of storage, the WHC decreased significantly for all treatments. Water holding capacity values of (15%) BS meatballs group recorded higher WHC throughout the period of storage (86.80±1.1, 82.90±0.1, 82.36±0.1, 78.67±0.6 and 67.91±0.3% for 0, 3,6 ,9 and 12 days , respectively, and was considerably ($p < 0.05$) greater than the control one . which showed the least WHC all over the storage periods (86.28±0.1, 81.61±0.5, 80.51±0.5, 76.55±0.7 and 65.40±0.1 %) for 0 , 3 ,6 ,9 and 12 days , respectively.

Table 5. Water holding capacity (%) of control , (0.1%) BHT and broccoli sprouts beef meatballs groups**.**

	WHC (%)				
Samples	0 day	3th day	6th day	9th day	12th day
Control	86.28±0.1a	81.61±0.5b	80.51±0.5b	76.55±0.7b	65.40±0.1c
0.1% BHT	87.21±0.5a	83.08±0.4ab	82.46±0.1a	79.92±0.5ab	68.47±0.6a
5% Broccoli sprouts	86.65±0.3a	82.36±0.1a	82.15±0.1a	77.84±0.5ab	67.08±0.1b
10% Broccoli sprouts	85.70±0.3a	82.78±0.2a	82.43±0.2a	78.04±0.4a	67.46±0.2ab
15% Broccoli sprouts	86.80±1.1a	82.90±0.1a	82.36±0.1a	78.67±0.6a	67.91±0.3ab

Values with different superscripts within the same column indicate a significant difference ($p \leq 0.05$).

As displayed in **table (6),** fat retention outcomes have no significant difference (p>0.05) between all treatments at zero day and ranged from (68.64±0.4 to 69.45±0.2 %). But at 3rd day of storage the fat retention decreased significantly for all treatments. It was observed that fat retention in meatballs enriched with broccoli sprouts groups recorded significance higher values in fat retention than control and (0.1%) BHT groups through the storage time.

Table 6. Fat retention (%) of control , (0.1%) BHT and broccoli sprouts beef meatballs groups.

	Fat retention (%)				
Samples	0 day	3th day	6th day	9th day	12th day
Control	69.45±0.2a	62.83±0.3b	58.37±0.3c	58.11±0.5b	56.15±1.1b
0.1% BHT	69.17±0.3a	67.84±0.3a	67.99±0.3ab	66.38±0.8a	65.50±0.3a
5% Broccoli sprouts	68.64±0.4a	68.48±0.5a	67.71±0.5b	64.39±0.8a	62.55±0.6a
10% Broccoli sprouts	69.35±0.2a	68.39±0.3a	67.35±0.2b	65.72±0.5a	63.72±0.9a
15% Broccoli sprouts	69.16±0.4a	67.61±0.4a	68.82±0.1a	65.92±0.4a	64.64±1.1a

Values with different superscripts within the same column indicate a significant difference ($p \leq 0.05$).

The variations in cooking loss values in beef meatballs during storage are displayed in **table (7) .** In this study it noticed that higher concentration of broccoli sprouts had a significant impact ($p < 0.05$) on reduction of cooking loss of meatballs as meatballs of 10% BS and 15% BS were significantly ($P \leq 0.05$) lower in cooking loss than control and 5% BS meatballs groups from the first day of storage time. At the same time cook yield values of beef meatballs during storage were presented in **table (8).** Cooking yield was significantly higher ($p < 0.05$) for meatballs enriched with broccoli sprouts groups than other control one from zero to 12 days.

Table 7. Changes in cooking loss values (%) of control , (0.1%) BHT and broccoli sprouts beef meatballs groups

	Cook loss (%)				
Samples	0 day	3th day	6th day	9th day	12th day
Control	28.19±0.1a	28.75±0.3a	30.40±0.6a	34.97±0.7a	34.86±0.7a
0.1% BHT	28.04±0.2a	26.55±0.1c	26.91±0.3c	28.50±0.7c	28.34±0.1c
5% Broccoli sprouts	27.49±0.2a	27.88±0.1b	28.53±0.1b	31.48±0.3b	31.36±0.3b
10% Broccoli sprouts	25.73±0.5b	25.89±0.3c	26.14±0.2c	27.80±0.1c	27.68±0.1c
15% Broccoli sprouts	24.56±0.1c	24.18±0.1d	25.92±0.2c	27.51±0.1c	27.30±0.1c

Values with different superscripts within the same column indicate a significant difference ($p \leq 0.05$).

Table 8. Changes in Cooking yield values (%) of control , (0.1%) BHT and broccoli sprouts beef meatballs groups

	Cook yield (%)				
Samples	0 day	3th day	6th day	9th day	12th day
Control	71.81±0.1c	71.25±0.2d	69.60±0.6c	68.82±0.6c	65.03±0.7c
0.1% BHT	72.29±0.2c	72.12±0.1c	71.47±0.1b	71.53±0.2ab	71.50±0.1a
5% Broccoli sprouts	73.51±0.5b	73.36±0.2b	73.09±0.3a	70.46±0.5b	68.52±0.3b
10% Broccoli sprouts	74.27±0.3b	74.42±0.4a	73.86±0.2a	71.69±0.4ab	72.20±0.1a
15% Broccoli sprouts	75.44±0.1a	75.16±0.1a	74.08±0.2a	72.58±0.4a	72.49±0.1a

Values with different superscripts within the same column indicate a significant difference ($p \leq 0.05$).

Table (9), showed the shrinkage (%) of control, (0.1%) BHT and broccoli sprouts beef meatballs groups and indicated that, at zero day there were no significant ($P > 0.05$) differences between control and the treated groups while from the 3rd day, shrinkage of cooked meatballs samples was significantly ($p < 0.05$) decreased in 10% and 15% BS meatballs groups comparing to control samples followed by 5% BS meatball group till the end of storage time

Table 9. Changes in shrinkage (%) values of control, (0.1%) BHT and broccoli sprouts beef meatballs groups.

	Shrinkage (%)				
Samples	0 day	3th day	6th day	9th day	12th day
Control	24.10±0.3a	25.25±0.4a	25.77±0.3a	26.61±0.1a	26.12±0.8a
0.1% BHT	24.08±0.3a	25.07±0.6ab	25.66±0.1a	25.06±0.1b	24.56±0.1b
5% Broccoli sprouts	24.35±0.1a	24.64±0.1ab	25.17±0.1a	24.73±0.1b	23.92±0.4b
10% Broccoli sprouts	24.41±0.3a	23.90±0.1bc	23.82±0.1b	23.15±0.4c	23.18±0.1bc
15% Broccoli sprouts	24.51±0.2a	23.31±0.1c	22.73±0.2c	22.57±0.1c	22.40±0.1c

Values with different superscripts within the same column indicate a significant difference ($p \leq 0.05$).

Table (10) , displayed the findings of sensory assessment of control beef meatballs and meatballs with (0.1%) BHT and (5%, 10%, 15%) broccoli sprouts powder. It is observed that, meatballs with 15% broccoli sprouts powder recorded the highest scores for sensory acceptability followed by meatballs with 10% broccoli sprouts powder compared to 0.1% BHT meatballs and 5% BS meatballs groups, while control group had fairly low acceptability. The highest scores of taste (9.90±0.10), flavor (9.80±0.10), color (9.95±0.10), tenderness (9.85±0.10) and appearance (9.95±0.10) were given by panelists for meatballs with 15% broccoli sprouts powder group followed by meatballs with 10% broccoli sprouts powder which reported taste of (9.55±0.11), flavor (9.50 ±0.10), color (9.60 ±0.12), tenderness (9.35 ±0.10) and appearance (9.65 ±0.10). Conversely, however, the lowest sensory properties were recorded in control, meatballs with (0.1%) BHT, and 5% broccoli sprouts powder.

Table 10. Sensory evaluation of control , (0.1%) BHT and broccoli sprouts beef meatballs groups

Treatment	Appearance	Color	Tast	juiciness	Tenderness	Overall acceptability
Control	9.25 ± 0.13^{b}	9.25 ± 0.13^{a}	9.10 ± 0.10^{c}	9.15 ± 0.10^{c}	9.05 ± 0.1^{c}	9.78 ± 0.006^{a}
0.1% BHT	9.20 ± 0.13^{b}	9.20 ± 0.13^{a}	9.15 ± 0.10^{c}	9.15 ± 0.13^{c}	9.05 ± 0.1^{c}	9.77 ± 0.003^{a}
5% Broccoli sprouts	9.31 ± 0.14^{b}	9.22 ± 0.12^{a}	9.00 ± 0.13^{c}	9.18 ± 0.12^{c}	9.09 ± 0.1^{c}	9.77 ± 0.006^{a}
10% Broccoli sprouts	9.65 ± 0.10^{ab}	9.24 ± 0.12^{a}	9.55 ± 0.11^{b}	9.50 ± 0.10^{b}	9.35 ± 0.10^{b}	9.78 ± 0.006^{a}
15% Broccoli sprouts	9.95 ± 0.10^{a}	9.25 ± 0.10^{a}	9.90 ± 0.10^{a}	9.80 ± 0.10^{a}	9.85 ± 0.10^{a}	9.78 ± 0.01^{a}

Values with different superscripts within the same column indicate a significant difference ($p \leq 0.05$).

DISCUSSION:

There are two key categories of natural antioxidants that should be included in a human diet, flavonoids and phenolic compounds. It was crucial to measure total concentration of flavonoids and phenols in Broccoli sprouts, as they are recognized to contain substantially higher in bioactive ingredients than the broccoli florets **(Bachiega et al. 2016).**

Obtained results in table (1) were agree with **Lee et al. (2018)** who reported that sprouts extracted by 70% methanol obtained higher TPC and TFC content than that extracted using hot water. According to **Paśko et al. (2018)**, the presence of bioactive and functional components, particularly phenolic agents and flavonoids, is responsible for the antioxidant properties of broccoli sprout extract (BSE). Consequently, broccoli sprouts' overall antioxidant activity demonstrated their capacity to prevent the generation of free radicals.

Chemical composition of control and treated uncooked beef meatball samples is given in **Table 2.** Increase in protein content in meatballs with broccoli sprouts can be linked to high metabolic activity in the early phases of germination, which encourages protein production **(López-Cervantes et al. 2013; Alhajri and Saad. 2023).** The ash content of meatballs enriched with broccoli sprouts significantly increased (p < 0.05) compared to control meatballs with the rise in concentration of broccoli sprouts and it may be attributed to broccoli sprouts are extremely abundant in minerals like calcium , iron, phosphorous potassium, Zinc, Selenium and magnesium **(Mir et al. 2021; Alhajri and Saad. 2023**). Meatball contained 5% BS, 10% BS and 15% BS had significant higher moisture levels (67.80±0.6, 68.86±0.07 and 71.34±0.4) respectively, compared to control and (0.1%) BHT beef meatball groups which had moisture level (66.28±0.7, 66.81±0.3), respectively. Elevation in moisture content could potentially attributed to the vegetables and broccoli sprouts powder incorporated in meatballs composition or may be the ability of broccoli sprouts powder that is high in fiber to retain excess water during the process of preparation. These observation agreed with **Ahmad et al. (2020)** who found that adding dietary fiber to chicken sausages that improves the emulsion stability and raises the moisture content; **Choi et al. (2015)** suggested that, diet have fiber sources can retained three or four times its weight of water.

Broccoli sprout-enriched meatball samples had a significantly higher fiber content (p < 0.05) than the control and BHT meatballs groups (0.1%). This may be attributed to the broccoli sprouts are fiber rich food and this was in line with **López-Cervantes et al. (2013); Alhajri and Saad. (2023)** who claimed that broccoli sprouts are regarded as nutrient-dense superfoods because they are high in fiber, protein, minerals , phytochemicals, and vitamins A and C. There is no significant differences (p>0.05) were observed in fat contents of all samples, This is attributed to the increased activity of lipolytic enzymes through the germination of sprouts (**Narsih et al. 2012**). The results inserted in this study are agree with **Atambayeva et al. (2023)** who recorded that The moisture of uncooked horse meat patties increased to 71.56% when germinated green buckwheat flour (GGBF) was added, compared to 65.32%) in the control sample. also high protein and law fat content of the uncooked horse meat patties. **Romero et al. (2014)** revealed that adding of dry soya sprouts to raw beef patties resulted in high protein, low moisture and low fat content of the end product .

Concerning the PH values , there were no significant (*p* > 0.05) differences between the pH values of all treated and control groups after preparation. Increasing the time of storage led to a significance difference of pH values gradually in all groups (P < 0.05). **Ouerfelli et al. (2019)** mentioned that continuous increase in the pH is due to the microorganisms and enzymatic activity that break down the proteins of meat to produce basic chemicals like amines and ammonia. In beef meatballs groups enriched with broccoli sprouts, pH values were significantly lower than the control and (0.1%) BHT ones. Decrease in pH of beef meatballs group enriched with broccoli sprouts was probably because phenolic compounds are present, especially acids that are present in the free, ester, and glycosidic forms, such as ferulic, p-hydroxybenzoic (PHA), and sinapic acids **(Lee et al. 2018 ; Dębski et al. 2021).**

Table (4), expressed TBA values of the control and treated beef meatballs groups. Generally, As storage time progress , TBA values rose dramatically for every group. TBARs values are linked to lipid oxidation of meat which is the primary factor causing deterioration in meat products, it was notable in this study that, broccoli sprouts were effective in reduction lipid oxidation specially when the concentration increase. TBA value of meatballs enriched with broccoli sprouts was lower than that of control sample which had the greatest and increased gradually with storage period. Compared to (0.1%) BHT meatballs group (synthetic antioxidant), meatballs enriched with variable concentrations of broccoli sprouts were more protected due to the natural antioxidant during storage for 12 days. Lower TBA values in meatballs enriched with broccoli sprouts groups because flavonoids contain bioactive and functional compounds, particularly phenolic compounds **(Paśko et al. 2018)**.

Similar to synthetic antioxidants, phenolic compounds can scavenge free radicals and chelate metal ions like Fe+2, which lowers the rate at which activated oxygen is formed **(Podsedek. 2007).** Numerous investigators noticed a decrease in TBARs when using antioxidants like green coffee in meatballs (**Mostafa and El Azab. 2022)**, black cumin in meatballs **(Oz . 2019)**, **Khan et al. (2020)** also observed decreased TBARs values of goat patties by adding of (0.1%) and (0.2%) chrysanthemum *morifolium* flower extract (CME). **Romero et al. (2014)** recorded that lipid oxidation in raw beef patties was inhibited when dried soybean sprouts (DSS) were added at various levels (0.5%, 1%, and 2%) and suggested that DSS could serve as a cost-effective natural source of antioxidant for meat products.

In regard to water holding capacity, it refers to ability of food product to substantially retain water against gravity. Throughout the storage period, a decrease in WHC was noted in all samples this may be attributed to protein denaturation and oxidation in the muscle during storage which cause reduction of its ability to hold water and changes of hydrogen bonds between protein and water leading to lower WHC **(Li et al. 2014)**. Data suggested that the uncooked beef meatballs samples enriched with broccoli sprouts significantly increased the water holding capacity, and this property increased with the higher percentage of broccoli sprouts added to meatballs. This considerable increase in WHC of meatballs containing broccoli sprouts samples may be explained by excess protein content in broccoli sprouts which able to hold water and form a network with it as functional properties led to enhanced WHC of beef meatball with broccoli sprouts as compared with control samples **(Dosh et al. 2015).**The acquired findings concur with **Soltanizadeh et al. (2014)** who confirmed that natural additives protect protein and improve WHC. **Atambayeva et al. (2023)** noted a notable rise in WHC of horse meat patties enriched by whole germinated green buckwheat due to its high protein content than pattiesenriched by non-germinated green buckwheat flour stored at 4 °C for 23 days .

The sensory characteristics and overall likability of a meat product are affected by its capacity to retain fat throughout the cooking and storage process. The outcomes recorded in **Table 6** revealed that meatballs enriched with broccoli sprouts had enhanced fat retention. could be attributed to the cooking which resulted in swelling of fiber and subsequently, the fat absorbed by the fiber and combined with protein matrix to hinder fat from moving from meat **(Mashau et al. 2021)**. The outcomes attained are consistent with **Atambayeva et al. (2023)** who found that incorporation of germinated green buckwheat sprouts (GGBF) to horse meat patties caused a minor rise in the retention of fat compared to non-germinated green buckwheat flour (NGGBF).

Cooking loss affect different quality criteria of meat because it indicate the loss of the water soluble nutrient and various constituents which responsible for taste, juiciness, color, tenderness and aroma, such as some amino acids or nucleotides **(Savaş et al. 2023).** It was noted that adding broccoli sprouts to the meatballs reduced their cooking loss values while, the cook loss of control beef meatballs increased during the refrigerated storage **table (7)**. Reduction in values of cooking loss in treated meatballs could be because broccoli sprouts contain phenolic compounds that may be able to hinder microbial reproduction and enzymatic activity, slowing the breakdown of muscle fiber microstructure and denaturation of protein (**Qian et al. 2020)** or possibly because broccoli sprouts powder had the capacity to retain extra water **(Essa and Mostafa. 2018).**

Concurrently, enhancing the cooking yield of meat products will enhance the weight of the product and, consequently, the profit margins. It will also attract consumers who like to eat more tasty and juicy food since it causes more fat and water to be retained. However, the elements employed for yield enhancement frequently offer a number of advantages. Enhancement of cooking yield for meatballs enriched with broccoli sprouts powder groups could be because broccoli sprout powder has more protein and more moisture than meat, which has a tendency to retain water. These results concur with those of **Ball et al. (2021)** who demonstrated that adding proteins derived from plants into beef patties increased cooking yield by retaining more moisture during the cooking processes . According to **Atambayeva et al. (2023)** incorporation of whole germinated green buckwheat with horse meat patties, enhanced the cooking yield for 23 days. Also, **Akhilesh et al. (2016)** found increase in cooking yield of chicken meatballs supplemented with green cabbage stored at 4 °C .

Shrinkage of cooked meat may be caused by denaturation of protein, which causes moisture to evaporate and fat and juice to drain out of the meatballs and It can serve as an indicator of the protein quality in the product **(López -Vargas et al. 2014)**. Decreased shrinkage in broccoli sprouts meatballs groups might be due to the higher protein and fiber contents of broccoli sprouts powder which aid meatball matrix in holding water during cooking **(Ragab et al. 2020)** and also may be attributed to the improved WHC of the broccoli sprouts powder which exhibited a protective effect against shrinkage **(Soltanizadeh and Ghiasi-Esfahani . 2015)**

Sensory properties as appearance, color, taste, flavor and tenderness are frequently regarded as crucial aspects to assess meat quality and acceptability, affecting the consumers' desire and preference to choice and select the food products **(Das et al. 2020).** Adding of non-meat components which had a particular color and aroma to formulation of meat product able to change the sensory characteristics of meat products. Thus, evaluating sensory attributes of the product is essential and adjust the formulations as needed **(Atambayeva et al. 2023).** Panelists noticed that meatballs incorporated with BS powder showed better juiciness and therefore improve tenderness of the product. This may be due to high content of moisture of broccoli sprouts (82.6%) **(Dziki et al. 2020)** , These outcomes concur with **Atambayeva et al. (2023)** who approved that the addition of germinated green buckwheat to horse patties somewhat reduced their textural parameters, including hardness, gumminess, chewiness, and springiness, moreover, their overall acceptability scores and juiciness improved instead of roasted buckwheat flour. Improved taste and flavor meatballs with broccoli sprouts powder may be due to high amounts of glucosinolates give a spicy taste to *Cruciferous* family sprouts such as radish and broccoli sprouts **(Gajewski et al. 2008)**.

There were no significance differences in color of control and treated meatballs; the meatballs were slightly lighter in color because of color of green broccoli sprouts powder but it had no adverse impact on the panelists' opinions in the meatballs. The appearance and overall acceptability of the manufactured meatballs product was unaffected by the addition of broccoli sprouts powder, as it received an extremely high rating (9 on a 10-point scale). The obtained outcomes matched **Atambayeva et al. (2023)** who indicated that addition of germinated green buckwheat sprouts flour to horse patties had no adverse effect on color or taste and flavor .The collected results indicate that panelists find meatballs enriched with 15% BS powder to be acceptable regarding its taste, flavor, color, appearance, and tenderness than the other two treated groups.

CONCLUSION

Findings of that study investigate that broccoli sprouts have a substantial amount of phenolics and flavonoids , additionally, a powerful antioxidant activity indicated their capacity to hinder the synthesis of free radicals. The addition of broccoli sprouts to meat sample improved pH, physical properties, nutritional value and oxidative stability of beef meatballs.The lipid oxidation was inhibited along the12 days of storage period. In light of all of these findings, it can be said that broccoli sprouts have a far stronger protective effect against the breakdown of fat in chilled meatballs, suggesting that they could be used in place of artificial antioxidants.

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