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Utilization of Artichoke Processing Wastes as Fat Replacer in Beef Sausage

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GLOBE artichoke canning industry generates considerable amounts of wastes. Incorporation these natural ingredients as a fat replacer in meat products processing could reduce these wastes and develop nutritionally enriched low-fat meat products. So, in this study, we aimed to utilize of these wastes (bracts) as fat replacer during processing beef sausage with different fat substitution levels (25, 50 and 100%). Control and treated samples (A25, A50 and A100) were stored after manufacturing in a refrigerator (4±1°C) for 12 days, while quality characteristics of sausages samples under investigation were evaluated. The results indicated that artichoke bracts contained phenolic compounds (328.33mg GAE/100g sample), flavonoids (332 mg Quercetin/ 100g sample) and had the highest antioxidant activity%, when compared with other artichoke wastes. The incorporation of artichoke bracts powder (ABP) into beef sausages formula caused an improving of physical quality criteria (cooking loss, cooking yield and shrinkage). While ABP addition to sausages formula significantly decreased their contents of total fat (fat reduction% in sample A100 recorded 54.58%), moisture and crude fiber increased, when compared to control sample. Furthermore, sausages samples containing ABP exhibited good sensory properties, especially in sample A25. Whereas replacing 100% of fat with ABP (sample A100) recorded the lowest microbial count. In conclusion, artichoke bracts powder (ABP) exhibited a good antioxidant effect, as well as has considerable amounts of fibers and minerals, and can be used successfully in manufacturing of meat products.

Keywords: Artichoke wastes, Inulin, GC-*MS*

Introduction

Global food crisis around the world increased alarmingly, and approximately 193 million people suffered from food insecure in the year 2021 (GRFC, 2022). Food loses and wastes increase the problem size, so reusing food wastes considered a good solution for sustainable management of food (EPA, 2016). These exploitable wastes, which contain functional ingredients, could be used in the nutraceutical industry (Zeaiter et al., 2019).

In this concept, globe artichoke canning industry generates about 60-80% of wastes (such as the bracts, stem, and leaves), while the hearts (which represent a small part of the artichoke plant) are mostly used (Jiménez-Moreno et al., 2019; Zeaiter et al., 2019). Globe artichoke, *Cynara scolymus L.*, is a perennial herbaceous crop, widely cultivated in the Mediterranean basin (Dosi et al., 2013). According to FAO statistics, Egypt produced about 308844 tonnes at the year 2020 (FAO, 2022). Although the agriculture wastes cause a real problem (Bekhet and Sharara, 2012), by contaminate the environment, artichoke by-products represent a potential source of bioactive phenolic compounds (Jiménez-Moreno et al. 2019), and contain inulin-type fructans

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with a degree of polymerization value ranged between 32 and 42 (which could be obtained from both bracts and stems of the artichoke wastes) according to Zeaiter et al. (2019). Inulin is a highly water-soluble carbohydrate and is not digested or absorbed in the small intestine, thus fermented in the colon by beneficial bacteria (acts as a prebiotic) (Lattanzio et al., 2009). Inulin is a functional food ingredient effects on humans and experimental animals by decreases blood glucose levels, enhanced calcium absorption, reduced LDL cholesterol, and inhibited various kinds of tumors (Kaur & Gupta, 2002). So, using inulin or natural sources of inulin in our daily foods, could enhance issues relate to health problems. Therefore, many previous studies used inulin or its natural sources (like edible parts of globe artichoke and Jerusalem artichoke tubers) as fat replacers (Berizi et al., 2017; El-Beltagy et al., 2007; Zhu et al., 2020).

To the best of our knowledge limited studies have been published on the use of globe artichoke wastes as a fat replacer in meat products, while no one performed on using globe artichoke bracts as a fat replacer during processing beef sausages. So, the main objectives of this study were to evaluate nutrients and active compounds of glop artichoke wastes, as well as study the effect of different concentrations of artichoke bracts powder during production of low-fat sausages, to define the proper concentration. Besides evaluate the effect of these additions on physical properties, chemical composition, sensory characteristics, and microbiological count in the final product (beef sausages).

Materials and Methods

Materials

Boneless lean beef meat and fat tissues were brought from the local market at Assiut city, Egypt. The artichoke (*Cynara scolymus* L) was obtained from local market at Assuit, Egypt. Texturized Soy was obtained from Food Technology Research Institute, Agricultural Research Center, Giza, Egypt (it was rehydrated by water at a ratio of 1:2 w/v and minced through 3 mm plate twice). Bread crust, skimmed milk, salt, fresh onion, and spices (7.27% laurel leaf powder; 4.37% cardamom; 5.22% nutmeg; 13.12% Arab yeast, 12.44% cinnamon,9.58% clove, 7.50% thyme, 27.75% cubeb and 12.75% white pepper) were purchased from local market at Assuit, Egypt. Furthermore, all chemicals in this study are analytical grade and most of these chemicals were purchased from EL-Gomhouria for Trading Chemicals and Drugs Co., Assiut, Egypt. Whereas 2,2-Diphenyl-1-picrylhydrazyl (DPPH), Folin-Ciocalteu reagent, and gallic acid were purchased from Sigma-Aldrich Chime, Germany.

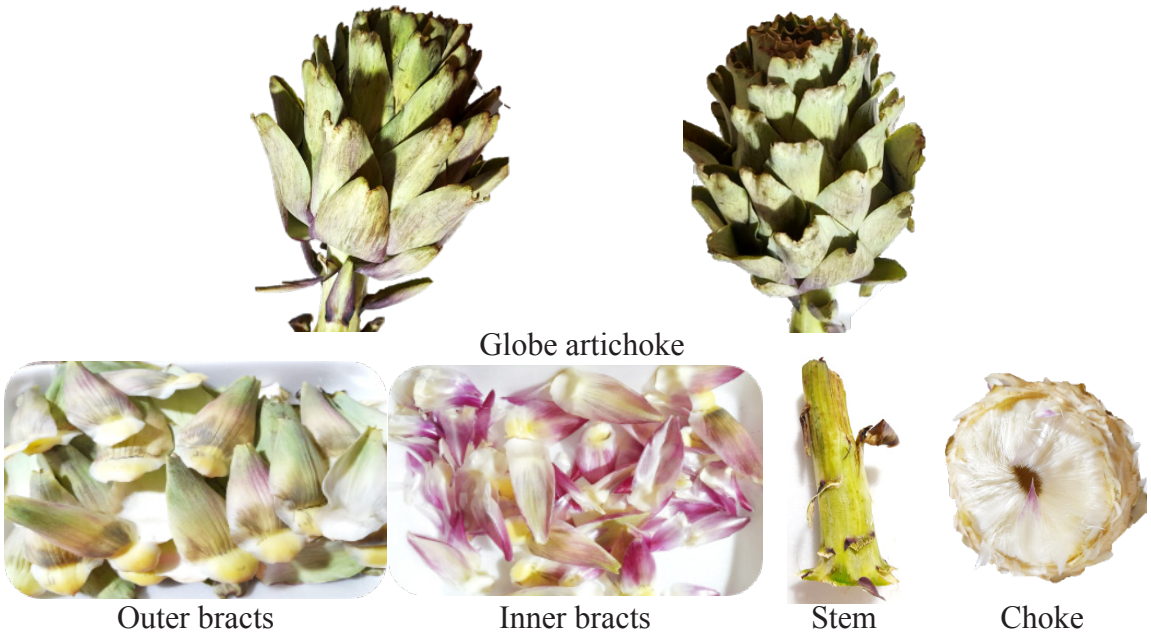

Fig. 1. Globe artichoke (Cynara scolymus L.) and its by-products (bracts, stem, and choke).

Methods

Preparation of Artichoke wastes

Globe artichoke samples were cleaned and cut into edible part and processing wastes (including outer and inner bracts, choke, and stem as seen in Fig.1). The sliced wastes were immediately immersed in 0.5% citric acid solution (to inhibit polyphenol oxidase activity), after that the wastes were draught, then packed in polyethylene bags, and kept in the freezer at -18 C. Before wastes usage, they have rinsed with tap water, and blanched at 100 ºC for 3 min., then dried at 50±2 °C for 18 hours in an electric air oven until constant weight. Coffee mill was used to mill recovered samples, and then powder was packed in polyethylene bags, and kept in the freezer at -18 °C until analysis.

Preparation of beef sausage

Beef sausage samples were prepared according to the method described by Heinz & Hautzinger (2007), using the ingredients listed in (Table 1). Meat and fat tissues were cut into small pieces and frozen at -18 °C for 24 h. The frozen meat and fat were ground to particles, after that the ingredients were blended to prepare sausage mixture emulsion, which was then stuffed by machine into mutton casings, and then the casings were closed and chipped. The natural mutton casings were obtained from the slaughterhouse and prepared according to El-Deep (1987). The freshly beef sausage was assigned to one of the following five treatments: control sausage (with 100% fat), sausage with 0.34% inulin (replacing 1.99 % of fat content), and sausage formulated with 25, 50 and 100% fat replacement with artichoke bracts paste. The ABP were added after rehydrated with water (at a ratio of 1:1 w/ v) and mixed. The samples were stored in polythene bags at 4±1°C for 12 days, and analyzed during zero time, 4, 8, and 12 days.

Analytical methods

Proximate composition analysis:

Moisture, protein, crude fat, crude fibers, and ash contents were determined according to the methods described in the AOAC (2000). Total carbohydrates were calculated by difference (Aly et al., 2021), whereas caloric value was calculated according to Mohamed (2005). Inulin content was determined according to the method of Rane et al. (2018).

Determination of minerals content:

The contents of calcium, magnesium, iron, and zinc were determined by ICAP6200 Inductively Coupled Plasma Emission Spectrometry (ICP-OES) (Thermo scientific) according to

TABLE 1. Ingredients were used in manufacturing beef sausage.

Ingredients	C	I	A25	A50	A100
Beef	60.0	60	60	60	60
Fat tissues	17.01	16.67	12.75	8.50	-
Water	7.00	7.00	7.00	7.00	7.00
Bread crust	1.40	1.40	1.40	1.40	1.40
Rehydrated soy	8.00	8.00	8.00	8.00	8.00
Skimmed milk	1.70	1.70	1.70	1.70	1.70
Fresh onion	1.50	1.50	1.50	1.50	1.50
Salt	1.90	1.90	1.90	1.90	1.90
Spices	1.50	1.50	1.50	1.50	1.50
Artichoke bracts paste (ABP*+water)	-	-	4.26 (2.12g ABP*+2.13g water)	8.51 (4.25g ABP*+4.26g water)	17.01 (8.5g ABP*+8.51g water)
Inulin	-	0.34	-	-	-

C: control sausage (contained 100% fat), I: sausages were produced by replacing 1.99 % of fat with inulin, A25: sausages were produced by replacing 25 % of fat with artichoke bracts paste, A50: sausages were produced by replacing 50 % of fat with artichoke bracts paste, A100: sausages were produced by replacing 100% of fat with artichoke bracts paste; ABP*: Artichoke bracts powder.

Isaac & Johnson (1985). While sodium and potassium contents were determined by a flame photometer corning 400 (Chapman and Pratt, 1961), phosphorus content was determined by spectrophotometer (Jackson, 1967)

Determination of total phenolic content, flavonoids, and antioxidant activity:

Total phenolics: Total phenolics content was determined using Folin-Ciocalteu reagent (Singleton and Rossi, 1965). Two hundred milligrams of sample were extracted for 2 h with 2 mL of 80% methanol containing 1% hydrochloric acid at room temperature on an orbital shaker adjusted at 200rpm. The mixture was centrifuged at 3000 rpm using a centrifuge (Sanyo, Harrier 18/80, refrigerated, UK) for 15 min and the supernatant decanted into 4 mL vials. Supernatants were combined and used for total phenolic assay. One hundred microliters of extract were mixed with 0.75 mL of Folin-Ciocalteu reagent (previously diluted 10-fold with distilled water) and allowed to stand at 22 °C for 5 min; 0.75 mL of sodium bicarbonate (60 g/L) solution was added to the mixture. After 90 min at 22 °C, absorbance was measured at 725nm using Spectrophotometer (67 Series, Jenway, UK, USA).

Determination of total flavonoids content: Total flavonoids content was determined according to the method described by Jia et al. (1999), with slight modifications. A 500µl of sample extract (prepared for total polyphenols content) was mixed with 2 ml of distilled water and subsequently with 0.15 mL NaNO2 (5%). After 6 min, 0.15 mL AlCl3(10%) was added and allowed to stand further 6 min. after that, 2 mL NaOH (4%) was added to the mixture. Immediately, distilled water was added to make the final volume up to 5 ml. Then, the mixture was mixed and allowed to stand for 15 min. The absorbance was measured by Spectrophotometer (67 Series, Jenway, UK, USA) against a blank at 510 nm. The results were expressed as mg of quercetin /100g of dry sample weight

*Determination of antioxidant activity:*The antioxidant activity was measured in terms of hydrogen-donating or radical-scavenging ability, using the stable radical 2,2-Diphenyl-1-picrylhydrazyl (DPPH) according to Brand-Williams et al. (1995). Samples of the wastes were extracted by maceration of 0.5 gm sample in 10 mL 70 % methanol for 24 h at the room temperature. The mixture was filtered, and the filtrate was kept for determination the antioxidant activity. DPPH was prepared by dissolving 9.85 mg in 100 ml 70 % methanol. A known volume of methanolic extract was dissolved in 70 % methanol then added to 335 µL DPPH. The mixtures were well shaken in a vortex (2500 rpm) for 1 min and then placed in the dark at room temperature for 30 min. The decrease in absorbance at 517 nm was determined with a JENWAY 6315 spectrophotometer. Absorbance detected without adding sample was used as control. The inhibition percentage of the DPPH radical was calculated according to the formula:

$$I\ \% = [(AB - AS)/AB] \times 100$$

Where I =DPPH inhibition %, AB=absorbance of control sample, AS = absorbance of a tested sample at the end of the reaction. Each assay was carried out in triplicate.

Gas chromatography-mass spectrometry (GC-MS) analysis

Volatile and semi-volatile compounds were carried out at the Department of Analytical Chemistry, Faculty of Science, Assiut University. The extract was prepared in methanol. The GC-MS analysis was done using a Thermo Scientific ™ TRACE 1300 coupled with an ISQ-7000; and the column was Thermo Scientific ™ TG-6MB 5ms (30m*0.250 mm*1.00 µm). The GC oven was kept at 100 °C for 15 min, then increased to 150 °C at a rate of 10 °C /min, then temperature increased to 200 °C at a rate of 5 °C /min, then temperature increased to 250 □ at a rate of 5°C /min, and finally temperature increased to 280 °C at a rate of 5 °C /min. Helium was used as the carrier gas at a flow rate of 0.5 mL/min. The mass spectrometer operated in electron ionization mode, and ion source temperature was 320°C, MS transfer line temperature 280 °C. Volatiles were identified using the NIST 17 mass spectral library (mainlib); and the results are expressed as % of the total GC area.

Microbiological analysis

Antibacterial activity:

The antibacterial activity of the artichoke bracts powder (ABP) was tested against 6 bacterial strains (*Bacillus cereus* AUMC No. B-52*, Escherichia coli* AUMC No. B-53*, Micrococcus luteus* AUMC No. B-112*, Pseudomonas aeruginosa* AUMC No. B-73*, Serratia marcescens* AUMC No. B-55*, and Staphylococcus aureus* AUMC No. B-54), which were individually inoculated in nutrient broth medium for 48 h to prepare inoculum. Sterile plastic petri plates (10 cm.) and medium of

nutrient agar were used in determination (Johnson and Case 2018). After media solidification 5 mm diameter cavities was cut (with sterile cork borer). After that methanolic extract of ABP was pipetted in the cavities (50 µL/cavity), then incubated at 28°C for 48 h. The inhibition zone diameters (in mm) around cavities were measured (Kwon-Chung and Bennett, 1992), and methanol was used as a negative control.

Microbiological count:

Microbiological counts were performed in sausage samples at zero time and after storage for 4, 8 and 12 days. Total bacteria count (TBC) was enumerated according to the method of Suleiman et al. (2011) on a nutrient agar medium after incubation at 37℃ for 48 h. Mycological analysis was performed by dilution plate method (Pitt and Hocking 2009), and Fungal count were enumerated on czapek's agar medium.

Physical methods

pH value:

Ten grams of minced meat sample blended with 90 ml distilled water, then the pH of suspension was measured by a pH meter (Hanna Instruments, Padova, Italy) (Vareltzis et al., 1997).

Cooking loss, cooking yield, and shrinkage:

- Cooking loss: Prepared beef sausage samples were weighted before cooking and then allowed to cool after cooking to room temperature. After cooling, the cooked beef sausage samples were reweighted, and the cooking loss was calculated according to Lee et al. (2008) as follows: Cooking loss (g/100g) = $\frac{Wr - Wc}{Wr}$ x 100

Where: Wr: the weight of raw sausage (g); Wc: the weight of cooked sausage (g).

- Cooking yield of different sausage samples was measured by subtracting cooking loss from 100 according to El-Nemr, (1979).
- Shrinkage percentage was calculated according to the method of George and Berry (2000) by using the following equations:

$$\% \text{ Shrinkage} = \frac{[\text{Uncooked diameter or length (cm)} - \text{Cooked diameter or length (cm)}] \times 100}{\text{Uncooked diameter or length (cm)}}$$

Sensory evaluation

Sensory evaluation was conducted using 10 semi-trained panelists who were asked to score appearance, texture, odor, taste, color, and overall acceptability. Hedonic ranking test where 9 (extremely accepted) to 1 (extremely rejected) (Gelman and Benjamin, 1989)

Statistical analysis

Analysis of variance and significant differences among means were tested by using SPSS software (version 16.0 for Windows, SPSS Inc., Chicago, IL). Analysis of Variance (ANOVA) was completed using Duncan's multiple comparison for mean difference testing.

Results and Discussion

Main parts of globe artichoke:

Yield of different parts:

Figure 2. illustrates the average yield of bracts (inner and outer), stem, choke, and edible part (receptacle), which recorded 62.04, 25.54, 4.37 and 8% respectively; whereas Lattanzio et al. (2009) reported that the percentage of edible portion was very low (less than 15 – 20 %). Moreover, Mahmoud et al. (2018) showed that edible part, bracts, and stem represented 24.21, 47.08 and 28.71% of the total weight of plant head respectively.

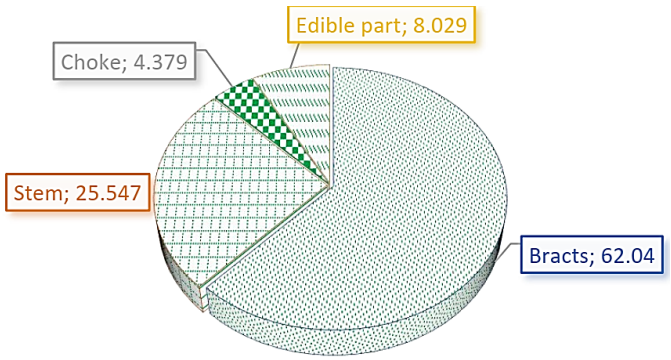

Fig.2: Percentages of different artichoke parts.

Phytochemicals in artichoke wastes

The results in Table 2 pointed that artichoke bracts powder (ABP) recorded the highest values of total phenolics contents and flavonoids, when compared to stem and choke powder. Meanwhile previous studies recorded higher values than our findings of total phenolics and total flavonoids (Gaafar & Salama, 2013). On the other hand, the data in the same table showed that the antioxidant activity of ABP (determined by DPPH scavenging activity%), was 79.36%, which was higher than the results obtained by El-Sayed et al. (2018), as they found that antioxidant activity of artichoke bracts (balady) recorded approximately 24%. Indeed, solvents and extraction techniques influence on results of phenolic compounds and antioxidant activity (Jiménez-Moreno et al., 2019; Noriega-Rodríguez et al., 2020).

Accordingly, the data in Fig.2 and Table 2 encouraged us to use bracts in our study, due to its high yield and it's valuable as a natural antioxidant.

Artichoke bracts powder (ABP):

Chemical composition

- *Gross chemical composition:*

Proximate composition of artichoke bracts powder (ABP) was represented in Table 3. The ash content of ABP was 5.65%, while crude fat, protein, and crude fiber content were 5.709, 10.38, and 27.64% respectively on dry weight basis. Whereas El-Sayaad et al. (1995) determined chemical composition of artichoke bracts on dry weight basis, and they found higher ash (10.33%), and fiber (37.69%) contents than our findings, while fat (5.65) and protein (9.46) contents were in the line with this study. Moreover, Mahmoud et al. (2018) found that ash, crude fat, protein, and crude fiber were 7.33, 1.78, 15.71 and 24.84%, respectively on dry weight basis in artichoke bracts. Although, our results were in the line with Claus et al. (2015) who found that ash and crude protein recorded 5.37 and 10.35% respectively in artichoke bracts, the content of crude fiber (44.23%) was nearly one and half time as our finding. These differences in chemical composition could be attributed to several factors like the cultivar type, the environmental effects and the method used in processing artichoke (Dabbou et al., 2014). Furthermore, total carbohydrate of artichoke bracts powder (ABP) in current research recorded 50.608%, while the caloric value recorded 295.44 kcal/100g. Whereas Villanueva-Suárez et al. (2019) showed lower content of carbohydrates in globe artichoke bracts (20.3g/100g dry matter) than our findings. On contrary, Umaña et al. (2021) found higher content of total carbohydrates (78.47% on dry weight basis) than our findings in artichoke bracts.

- *Inulin:*

Inulin content in bracts recorded 5.69 g/ 100g on dry weight basis. Likewise, Mahmoud et al. (2018) found inulin content in globe artichoke bracts ranged between 5.54 and 6.58% on dry weight basis in blanched and raw bracts, respectively. Sharara & Ghoneim (2011) found higher content of inulin than our findings. Differences in variety, harvesting times and the geographical locations (Ruiz-Cano et al., 2014; Lattanzio et al., 2009) affecting their chemical composition content.

- *Mineral composition:*

In the present study potassium, phosphorus, calcium, sodium, magnesium, iron, and zinc were determined in artichoke bracts powder (ABP) (Table 3), which recorded 1255.375, 211.0696, 417.331, 318.826, 232.2513, 32.7828 and 4.2359 mg/ 100g, respectively. The data revealed that potassium was the most abundant mineral, which compatible with previous studies (Rincon et al., 2007); Pandion et al., 2011). Meanwhile Mahmoud et al. (2018) showed lower values of Ca, Na, Mg, Fe and Zn in raw artichoke bracts, while K recorded higher value (3089.12 mg/100 g on dry weight basis) than our findings; and such differences could be attributed to head fraction, genotype, location, and season.

TABLE 2. Total phenolics, Total flavonoids, and antioxidant activity% determination in artichoke wastes.

Artichoke wastes	Stem	Bracts	Choke
Total phenolics (mg GAE/100g sample)	107.67±3.05b	328.33±2.52a	81.66±2.08c
Total flavonoids (mg Quercetin/ 100g sample)	91.66±3.05b	332±97.32a	59.33±4.51b
Antioxidant activity%	29.17±0.866b	79.36±0.511a	15.26±1.072c

[a-c] Means of triplicate ±SD (standard deviation) with different small letters in the same row differ significantly at $p<0.05$.

TABLE 3. Gross chemical composition, caloric value, and minerals content of artichoke bracts powder (ABP)

Parameters%	Artichoke bracts powder (ABP)
Moisture%	8.04±0.014
Ash*	5.65±0.153
Crude fat*	5.709±0.068
Protein*	10.38±0.023
Crude fiber*	27.64±0.03
Total carbohydrates**	50.608±0.032
Inulin*	5.69±0.41
Caloric value	295.44±0.837
Minerals content* (mg/ 100g)**	
K	1255.375±0.005
P	211.069±0.006
Ca	417.331±0.003
Na	318.826±0.003
Mg	232.251±0.005
Fe	32.783±0.002
Zn	4.236±0.005

*Means± SD (standard deviation) of duplicate (g/ 100g on dry weight basis);

** Total carbohydrates calculated by differences. *** Means± SD (standard deviation) of triplicate.

Gas chromatography and mass spectrometry analysis (GC-MS) analysis

Gas chromatography and mass spectrometry analysis (GC-MS) of compounds was carried out in methanol extract of ABP. The GC-MS of 43 compounds were detected and are shown in Table 4. The most abundant compound was Butyric acid, 4-pentadecyl ester and recorded 9.78% (Actually, Chandan (2016) referred to the important of butyric acid in the colon as a potential anticancer agent). Meanwhile several fatty acids and their esters and aldehydes form in artichoke bracts powder were detected, like 9-Hexadecenoic acid (which has anti-eczematic effect and protect micromembranes according to Brintha et al. (2017) and Oleic Acid (which has anti-inflammatory and prevent cancer effect according to Tayade et al. (2013), Octadecanoic acid, 2-hydroxy-1,3-propanediyl ester, 9,12,15-Octadecatrienoic acid,2,3-bis[(trimethylsilyl)oxy]propyl ester, (Z,Z,Z)-(which has anti-inflammatory, anti-diabetic and antioxidant properties according to Chinnasamy et al., (2018)), 9-Octadecenoic acid, (2-phenyl-1,3-dioxolan-4-yl)methyl ester, cis- (which has anti-eczematic, anti-inflammatory (Brintha et al. (2017)) and antimicrobial effects according to Kadhim et al. (2016), Octadecanoic acid, 2,3-bis(acetyloxy)propyl ester, 9-Octadecenoic acid (Z)-, tetradecyl ester, Oleic acid, eicosyl ester (which has anti-inflammatory and anti-cancer effects and lowering cholesterol according to Kumar et al. (2018), Hexadecanoic acid,1-(hydroxymethyl)-1,2-ethanediyl ester, Hexadecanoic acid,1-[[[(2-aminoethoxy) hydroxyphosphinyl]oxy]methyl]-1,2-ethanediyl ester, Octadecanoic acid,3-[(1-oxohexadecyl) oxy]-2-[(1-oxotetradecyl)oxy]propyl ester, Docosanoic acid, 1,2,3-propanetriyl ester (which has emulsifying properties according to Daffodil et al. (2012), Eicosanoic acid,2-[(1-oxohexadecyl) oxy]-1-[[(1-oxohexadecyl)oxy]methyl]ethyl ester (Indeed, Mohammed et al. (2016) referred to the anti-inflammatory and anti-melasma properties of eicosanoic acid, 2-(acetyloxy0-1-[(acetyloxy)methyl]ethyl ester), Octadecanal, 2-bromo- (which has anti-inflammatory and anti-apoptotic influences according to Dinesh Kumar et al., (2018)). Furthermore, triglycerides like Triarachine (which considered as energy source and has a role in dietary fat transporters), and Tripalmitin were detected. Whereas 3,5,9-Trioxa-4-phosphaheptacos-18-en-1-aminium,4-hydroxy-N, N, N-trimethyl-10-oxo-7-[(1-oxo-9-octadecenyl) oxy]-, hydroxide, inner salt, 4-oxide, (R)-(Choline, hydroxide, dihydrogen phosphate, inner salt, ester with 1,2-dipalmitin), which was considered a phospholipid.

Moreover, Table 4 shows derivatives of amino acids compounds like, N-2,4-Dnp-L-arginine (which has a therapeutic effect on tumors according to Kamstra et al. (2015), and

Glycine, N-[(3α,5á,7α,12α)-24-oxo-3,7,12-tris[(trimethylsilyl)oxy]cholan-24-yl]-, methyl ester (which has important role as anti-bacterial according to Ganesh and Vennil (2011).

On the other hand, the results in the present study showed other active compounds in ABP like Digitoxin (which has anti-cancer effect according to Elbaz et al. (2012), and has anesthetic, cardiotonic and diuretic effects (Brintha et al., 2017), Cycloheptasiloxane, tetradecamethyl-(which has antimicrobial and antiseptic properties according to Hameed et al. (2015), 7-Methyl-Z-tetradecen-1-ol acetate (which has anti-cancer, anti-inflammatory and hepatoprotective (Hameed et al., 2015; Huang & Irwin, 2006).

Moreover, Table 4 reveals that artichoke bracts powder had steroid compounds like Ethyl iso-allocholate (which has antieczematic (Brintha et al., 2017), antimicrobial and anti-inflammatory effects according to Hameed et al., (2015)), Curan-17-oic acid,19-(acetyloxy)-2,16-didehydro-20-hydroxy methyl ester, (19S)-4(14),9(10)-dien (which has anti-yeast activity according to Hussein et al. (2016), and 5-Chloro-6beta-nitro-5alpha-cholestan-3-one.

Furthermore, the GC-MS analysis showed several bioactive compounds with important biological activity in ABP like Cinnamic acid, 4-hydroxy-3-methoxy (which has a promising potential as anticancer according to Mumtaz et al 2021), 9,10-Secocholesta-5,7,10(19)-triene-3,24,25-triol, (3α,5Z,7E)-(which has anti-eczematic, anti-osteoporotic and inhibits prostaglandin-E2 9-reductase (Brintha et al., 2017), 1-Monolinoleoylglycerol trimethyl silyl ether (antimicrobial activity according to Al Bratty et al. (2020), Sarreroside (which has respiratory analeptic effect, anti-cancer, anti-protozoa, dementia treatment, hepatoprotectant, and anti-eczematic according to Brintha et al. (2017), Oxiraneoctanoic acid, 3-octyl-, cis-(Actually, Hussein et al. (2016a) showed that Oxiraneoctanoic acid, 3-octyl-,methyl ester had antibacterial activity), 7,8-Epoxylanostan-11-ol, 3-acetoxy- (which has antimicrobial, anti-inflammatory effect according to Hassan et al. (2014); Lee et al. (2013), and n-Butyl ricinoleate (it was mentioned to the anti-bacterial and anti-mycobacterial properties of ricinoleic acid-derived compounds (Kuppala et al., 2016).

Antibacterial activity

The antibacterial potential of artichoke bracts powder methanolic extract (50 µl) against six pathogens was assessed in terms of zone inhibition of bacterial growth, and the results were illustrated in Table 5. The zones were in the range of 6-7 mm. ABP recorded the maximum zone formation against *Pseudomonas aeruginosa, Serratia marcescens* and *Staphylococcus aureus*. The presence of active compounds in ABP (Table 4) explained the anti-bacterial activity of ABP extract. The data showed lower zones than other studies, which were carried out by Gaafar & Salama (2013) and El Sohaimy (2014) due to the variation in solvent type during extraction.

Sausage manufacturing

Physical characteristics:

Cooking yield and cooking loss:

Replacing fat with inulin and different levels of ABP during processing sausages and its effect on cooking yield and cooking loss are shown in Fig. 3. Using inulin or ABP during processing sausages increased cooking yield significantly ($p < 0.05$) and decreased the cooking loss, when compared to control sample. Besides Fig.3 shows that sample A100 (100% fat replacement with ABP) recorded the highest cooking yield (75.65%) and lowest cooking loss. Whereas EL-beltagy et al. (2007) reported that cooking yield of patties formulated with 100% fat replacement with Jerusalem artichoke tubers recorded 68.21%. The enhancement of cooking yield in our study could be attributed to the ability of artichoke bracts fibers to keep water. Similar observations were reported by El-Damaty et al. (2016). The decrease in fat content caused hydrophobicity lowering effect of the formulas (EL-beltagy et al., 2007). Meanwhile Gad EL Rab et al. (2019) mentioned to the relationship between the high fiber content and enhancement of cooking yield, WHC, cooking loss and shrinkage.

Shrinkage:

Figure 4 illustrates the effect of inulin and ABP as fat replacers on sausages shrinkage%. Control sample recorded the highest shrinkage of length percentage, while using inulin or ABP to replace fat decreased shrinkage significantly ($p < 0.05$). The findings in this study were on the line with previous study was conducted by El-Damaty et al. (2016). Although, adding fat during meat products processing prevents protein shrinkage during cooking according to Brewer, (2012), replacing 100% fat with ABP in this study recorded the lowest shrinkage of diameter percent, and decreased shrinkage significantly ($p < 0.05$), when compared with control sample. The results in this study reflected the improvement effect of ABP as a fat replacer without causing any shrinkage in the final product, while using inulin (sample I) caused a non-significant ($p > 0.05$) increase in shrinkage of diameter.

TABLE 4. Gas chromatography (GC)-Mass Spectrometry (MS) analysis results of methanolic extract of artichoke bracts powder (ABP).

NO.	Retention time (min)	Compound	Value (%)
1	10.19	5α-Cholestan-2-one, oxime	1.34
2	10.56	1,3-Dioxane,5-(hexadecyloxy)-2-pentadecyl-, trans-	0.99
3	13.28	2-Myristynoyl pantetheine	0.66
4	17.44	N-2,4-Dnp-L-arginine	0.38
5	18.5	Digitoxin	1.97
6	19.46	Heptasiloxane,1,1,3,3,5,5,7,7,9,9,11,11,13,13-tetrade camethyl-	1.57
7	19.77	Cycloheptasiloxane, tetradecamethyl-	0.81
8	22.52	Octadecanoic acid, 2-hydroxy-1,3-propanediyl ester	0.63
9	23.74	(5á) Pregnane-3,20á-diol,14α,18α-[4-methyl-3-oxo-(1-oxa-4-azabutane-1,4-diyl)]-, diacetate	0.77
10	25.07	Butyric acid, 4-pentadecyl ester	9.78
11	25.64	7-Methyl-Z-tetradecen-1-ol acetate	0.85
12	26.35	Ethyl iso-allocholate	0.41
13	26.73	Cinnamic acid, 4-hydroxy-3-methoxy-, {5-hydroxy-2-hydroxymethyl-6-[2-(4-hydroxy-3-methoxyphenyl) ethoxy]-4-(6-methyl-3,4,5-trihydroxytetrahydropyran-2-yloxy) tetrahydropyran-3-yl} ester	0.42
14	27.03	9,10-Secocholesta-5,7,10(19)-triene-3,24,25-triol, (3á,5Z,7E)-	0.66
15	27.26	1-Monolinoleoylglycerol trimethylsilyl ether	0.82
16	27.72	Octadecanal, 2-bromo-	0.61
17	28.04	9,12,15-Octadecatrienoic acid,2,3-bis[(trimethylsilyl)oxy] propyl ester, (Z, Z, Z)-	0.47
18	29.37	9-Hexadecenoic acid	3.33
19	30.54	Curan-17-oic acid,19-(acetyloxy)-2,16-didehydro-20-hydroxy-, methyl ester, (19S)-4(14),9(10)-dien	0.38
20	30.73	Pregn-4-ene-3,20-dione,17,21-dihydroxy-, bis(O-methyloxime)	1.09
21	31.39	Cholesta-8,24-dien-3-ol, 4-methyl-, (3α,4α)-	0.51
22	31.69	Oxiraneoctanoic acid, 3-octyl-, cis-	1.02
23	32.58	Estra-1,3,5(10)-trien-17 α -ol	0.44
24	33.11	9-Octadecenoic acid, (2-phenyl-1,3-dioxolan-4-yl) methyl ester, cis-	1.03
25	34.03	Sarreroside	0.87
	34.82	Glycine, N-[(3α,5 α,7α,12α)-24-oxo-3,7,12-tris[(trimethylsilyl)oxy] cholan-24-yl,-[methyl ester	0.79
26	36.72	Octadecanoic acid, 2,3-bis(acetyloxy)propyl ester	0.65
27	37.69	9-Octadecenoic acid (Z)-, tetradecyl ester	0.93
28	38.13	Oxiraneundecanoic acid, 3-pentyl-, methyl ester, trans-	0.86
29	39.45	7,8-Epoxylanostan-11-ol, 3-acetoxy-	1.60
30	39.54	Oleic acid, eicosyl ester	1.19
31	39.64	n-Butyl ricinoleate	1.27
32	42.98	Oleic Acid	4.42
33	43.65	Triarachine	2.15
34	44.07	Dodecyl cis-9,10-epoxyoctadecanoate	3.41
35	48.86	Tripalmitin	2.44
36	49.45	Hexadecanoic acid,1-(hydroxymethyl)-1,2-ethanediyl ester	7.94
37	50.11	Hexadecanoic acid,1-[[[(2-aminoethoxy) hydroxyphosphinyl] oxy] methyl]-1,2-ethanediyl ester	4.50
38	50.68	3,5,9-Trioxa-4-phosphaheptacos-18-en-1-aminium,4-hydroxy-N, N, N-trimethyl-10-oxo-7-[(1-oxo-9-octadecenyl) oxy]-, hydroxide, inner salt, 4-oxide, (R)-	5.27
39	51.23	Eicosanoic acid,2-[(1-oxohexadecyl) oxy]-1-[[(1-oxohexadecyl) oxy] methyl] ethyl ester	7.79
40	51.4	Octadecanoic acid,3-[(1-oxohexadecyl) oxy]-2-[(1-oxotetradecyl) oxy] propyl ester	7.42
41	52.19	5H-Cyclopropa [3,4] benz[1,2-e] azulen-5-one,3,9,9a-tris(acetyloxy)-3-[(acetyloxy)methyl]-2-chloro-1,1a,1b,2,3,4,4a,7a,7b,8,	4.28
42	53.53	Docosanoic acid, 1,2,3-propanetriyl ester	6.21
43	53.82	5-Chloro-6beta-nitro-5alpha-cholestan-3-one	5.11

TABLE 5. Antibacterial activity of artichoke bracts powder methanolic extract.

Bacterial strains	Inhibition zone (mm)		
	Artichoke leaves powder methanolic extract	Methanol	Standard cont.
Bacillus cereus (+ve) AUMC No. B-52	6	-	20
Escherichia coli (-ve) AUMC No. B-53	6	-	23
Micrococcus luteus (+ve) AUMC No. B-112	6	-	22
Pseudomonas aeruginosa (-ve) AUMC No. B-73	7	-	18
Serratia marcescens (-ve) AUMC No. B-55	7	-	22
Staphylococcus aureus (+ve) AUMC No. B-54	7	-	20

AUMC No: Assiut University Mycological Center.
Standard cont.: Chloramphenicol as antibacterial standard.\

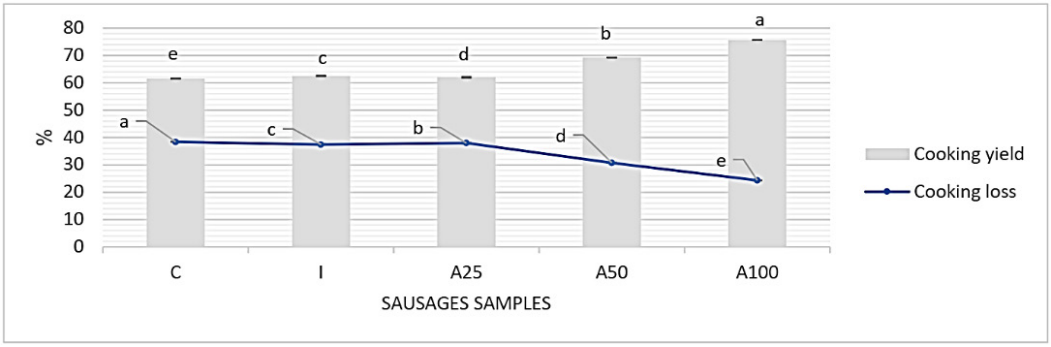

Fig. 3. Cooking yield and cooking loss of sausages samples without and with ABP addition.
C: control sausage (with 100% fat), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); [a-e] Means of triplicate ±SD (standard deviation) with different small letters differ significantly at p<0.05.

Chemical composition

The proximate composition of meat sausages without and with ABP as a fat replacer is presented in Table 6. The data in this study revealed that sausages formulated by replacing 1.99% fat with inulin showed non-significant differences in moisture content, when compared with control sample. Whereas Berizi et al. (2017) found that moisture content in emulsion type sausage formulated with different amount of inulin (3-6%) and water recorded higher moisture content (62.9-72.2%), when compared to control (59.9%). From the results presented in Table 6, it could be noticed that, replacing 50 and 100% of fat with ABP (samples A50 and A100) had significantly ($p < 0.05$) higher moisture content (63.75 and 66.66% respectively) than control (57.66%). This increase could be attributed to the improvement in the water holding capacity of the sausages formulated with globe artichoke (El-Damaty et al. (2016)). On the other hand, in the same table, it could be noticed that protein content decreased non-significantly ($p > 0.05$) with the increase in ABP percentages. Likewise, Nasonova & Tunieva (2019); Berizi et al. (2017) noticed non-significant ($p > 0.05$) effect on protein content of sausages when they used fat replacers as compared with control sample. Regarding of fat, the data in Table 6 shows a significant ($p < 0.05$) decrease in fat content by increasing the levels of fat substitutions with inulin or ABP. Our findings were on the line with previous study by EL-beltagy et al. (2007). Moreover, Table 6 illustrates the percentage of fat reduction, and sample A100 recorded the highest percentage (54.58%).

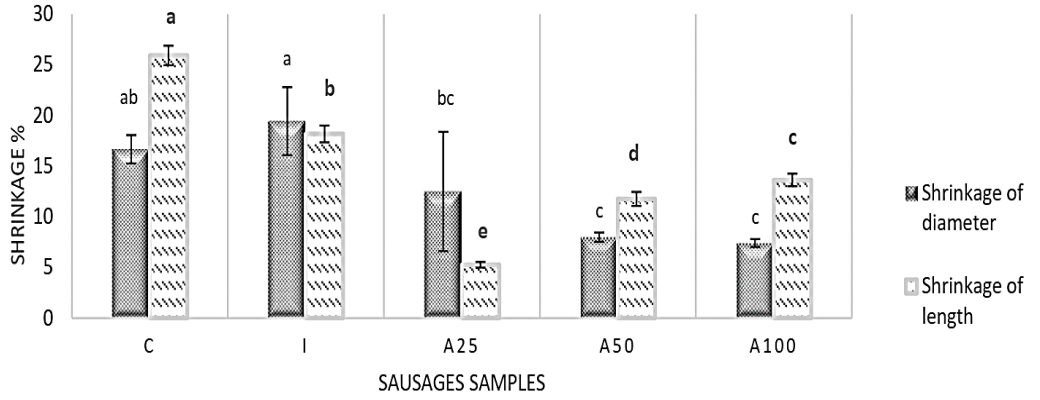

Fig. 4. Shrinkage percentage of sausages samples without and with ABP addition.
C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); [a-e] Means of triplicate ±SD (standard deviation) with different small letters differ significantly at p<0.05.

Meanwhile, Nasonova & Tunieva (2019) found that the addition of different types of fat replacers (inulin, a mixture of hydrocolloids, soy protein, and collagen protein) instead of backfat reduced the fat content in cooked sausages by 41.0-44.6%, which was lower than our findings. Furthermore, crude fiber content had a significant increase ($p < 0.05$) with the increase of substitution level of ABP. These results are in quite comparable to those obtained by El-Damaty et al. (2016).

Sensory evaluation

Sensory characteristics of sausages without and with fat substituted with I and ABP (at different levels) and their appearance were shown in Table 7 and Fig.5. Data in Table 7 showed that sausage sample which contained inulin (I) recorded the best scores, as all sensory parameter increased (non-significantly as $p > 0.05$), when compared to control. Likewise, Berizi et al. (2017) found non-significant differences in most of sensory parameters when they used inulin to substitution of fat in emulsion type sausage. Although the scores of organoleptic properties reduced by increasing the level of fat substitution, there were non-significant differences between all samples and control (except for sample A100 which differ significantly and had the lowest scores in texture and color parameters). Meanwhile, Souha et al. (2020) used artichokes leaves powder in processing dried sausages, and found non-significant differences in color, flavor, and odor, when compared with control, although panelists judged samples as moderately dark. Moreover, Bekhet & Sharara (2012) used artichoke waste extracts during processing meat patties and samples were accepted by panelists in all organoleptic properties. Furthermore, El-Damaty et al. (2016) used globe artichoke as a fat replacer and showed non-significant decrease in color, odor, and appearance when they increase the fat substitution level in chicken burgers.

Storage of sausages samples

pH changes

Figure 6 shows that replacing fat by inulin (sample I) had non-significant differences ($P > 0.05$) in pH values, when compared to the control sample. Likewise, Berizi et al. (2017); Nasonova & Tunieva (2019) found that using of inulin as a fat replacer did not significantly affect pH. Whereas Zhu et al. (2020) showed that animal fat reduction had little impact on pH; consequently, sausages quality and shelf life. On the other hand, using ABP as a fat replacer during manufacturing sausages caused significant ($P < 0.05$) decrease in pH values, and sample A100 recorded the lowest pH value between all fresh sausage samples. Similar trend in pH values were observed in previous studies (Bekhet and Sharara (2012); El-Damaty et al. (2016); Souha et al. (2020). These data confirmed that ABP as a fat replacer affected differently on pH values, when compared with pure inulin. By the increase of storage period, pH values decreased in all samples under investigation; as microorganism strains grow and produce acids, which effect on pH values (Bekhet & Sharara 2012).

TABLE 6. Effect of replacing fat with inulin and different levels of ABP on chemical composition (on dry weight basis %) in beef sausages.

Sausage samples	Moisture	Protein	Fat	Fat reduction (%)	Crude fiber
C	$57.665^{b}\pm2.58$	$62.16^{a}\pm0.23$	$51.7525^{a}\pm3.09$	-	$1.3^{d}\pm0.014$
I	$58.805^{b}\pm1.51$	$64.245^{a}\pm0.36$	$45.644^{b}\pm0.145$	11.80	$0.74^{e}\pm0.028$
A25	$59.835^{b}\pm0.33$	$47.914^{a}\pm13.24$	$48.108^{ab}\pm0.58$	7.04	$1.49^{c}\pm0.007$
A50	$63.755^{a}\pm1.24$	$48.514^{a}\pm11.20$	$38.999^{c}\pm0.227$	24.64	$3.61^{b}\pm0.007$
A100	$66.66^{a}\pm0.62$	$50.715^{a}\pm0.62$	$23.5065^{d}\pm0.29$	54.58	$5.36^{a}\pm0.028$

C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); $^{a\text{-}e}$ Means ±SD (standard deviation) of duplicate with different small letters in the same column differ significantly at $p<0.05$.

TABLE 7. Sensory characteristics of sausages without and with using fat replacers .

Sausage samples	Appearance (9 points)	Texture (9 points)	Odor (9 points)	Taste (9 points)	Color (9 points)
C	$6.50^{ab}\pm1.29$	$7.37^{a}\pm1.70$	$6.50^{a}\pm2.38$	$6.50^{ab}\pm2.38$	$6.50^{a}\pm1.29$
I	$7.75^{a}\pm0.50$	$8.00^{a}\pm0.82$	6.50a±0.57	$7.00^{a}\pm0.00$	7.25a±0.96
A25	$7.25^{a}\pm0.50$	$7.63^{a}\pm0.75$	$5.75^{a}\pm0.96$	$5.75^{ab}\pm0.50$	$6.50^{a}\pm0.57$
A50	$6.63^{ab}\pm1.11$	$6.50^{ab}\pm0.57$	$5.25^{a}\pm1.26$	$5.50^{ab}\pm0.57$	$6.00^{ab}\pm0.82$
A100	$5.25^{b}\pm1.50$	$5.25^{b}\pm0.96$	$5.00^{a}\pm1.41$	$5.00^{b}\pm0.00$	$4.75^{b}\pm0.50$

C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); $^{a\text{-}e}$ Means with different small letters in the same column differ significantly at $p<0.05$.

Fig. 5. Appearance of sausages samples without and with using fat replacers.

C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement).

Figure 6 illustrates that pH values of control sample decreased from 6.46 to 5.27 during the storage period up to 12 days, while sample A100 had the lowest significant ($P < 0.05$) pH value (5.17). The results in this study were in accordance with previous study which conducted by Ergezer et al. (2018). Furthermore, mean square and p-values for pH showed a significant effect ($P<0.05$) of treatments (replacing fat with inulin and ABP), storage time and their interactions (Table 8).

Microbiological changes

Table 9 illustrates the effect of using inulin and ABP as fat replacers during processing sausages on total bacteria count (TBC). Mean of groups (related to treatments) in the same table showed that samples A50 and A100 recorded the lowest TBC. These results reflected the antibacterial effect of ABP as it contained several active compounds (Tables 4 and 5). Likewise, Bekhet & Sharara (2012) found that meat patties samples containing artichoke extract recorded lowest TBC at the end of cold storage period. On contrary, Souha et al. (2020) found non-significant increase in total viable bacteria at zero time when they used artichoke powder during processing sausages. Whereas a previous study was conducted by Bakr et al. (2020) found that total viable bacteria count increased after addition of Jerusalem artichoke extract to bio-yogurt, when compared to control sample. Indeed, control sample excluded because it gets spoiled at the day 12 of storage. Likewise, Bekhet and Sharara (2012) noticed higher numbers of total count of bacteria at the day 9 of storage, so it could not be detected.

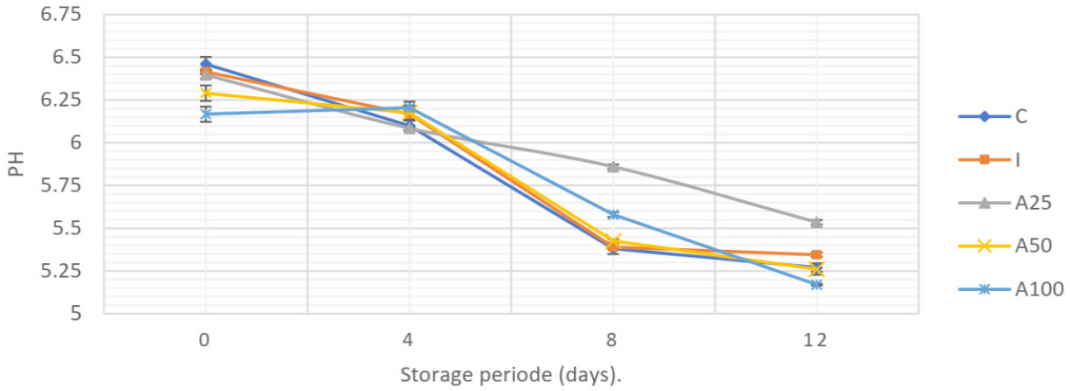

Fig. 6. Effect of replacing fat by inulin and ABP on pH values in sausages samples.

C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); (Means of triplicate ±SD (standard deviation)).

TABLE 8. Mean squares and P-values (in parentheses) for pH values

Factor	df	Mean Square (p-value)
Treatment[1]	4	0.098(0.000*)
Storage time[2]	3	4.804 (0.000*)
treatment × storage time	12	0.069(0.000*)

[1] Treatments: C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); [2]Storage time: 0,4,8, and 12 days; df: degrees of freedom; *Statistically significant at $P<0.05$

Meanwhile values of groups mean (related to storage time) in Table 9 showed that the increase in storage period up to the fourth day had significant ($P < 0.05$) decrease in TBC, while day 8 showed non-significant ($p > 0.05$) effect. This decrease could be attributed to the increase in lactic acid bacteria during storage.

Regarding fungal count, the mean of group's values reveals that using inulin to partially replacement of fat recorded the highest fungal count. On the other hand, using ABP to replace fat during sausages processing decreased fungal count significantly ($p < 0.05$), and sample A100 (100% replacement of fat with ABP) recorded the lowest count. Table 9 shows the effect of storage period, as fungal count increased at the eighth day of storage. Furthermore, Table 9.1 shows the effect of treatments, storage time and their interactions in bacterial and fungal counts.

TABLE 9. Microbiological counts (log CFU/g) in sausages samples without and with ABP addition during storage for 12 days.

Item	samples	Storage period				
		Zero time	4	8	12	Mean of groups
Total Bacterial count (TBC)	control	4.98±0.155	5.12±0.132	4.89±0.047	-	-
	I	4.88±0.072	4.79±0.039	4.75±0.032	4.93±0.087	**4.84^{ab}**
	A25	5.316±0.063	4.83±0.027	4.76±0.032	4.98±0.103	**4.97^{a}**
	A50	4.83±0.083	4.69±0.036	4.92±0.022	4.28±0.065	**4.678^{c}**
	A100	4.69±0.037	4.52±0.301	5.05±0.157	4.89±0.087	**4.77^{bc}**
	Mean of groups	**4.938^{A}**	**4.782^{B}**	**4.874^{AB}**	-	-
Fungal count	control	2.64±0.113	2.98±0.129	3.08±0.127	-	-
	I	3±0.093	3.13±0.058	3.39±0.045	2.66±0.094	**3.04a**
	A25	2.41±0.195	3.15±0.069	2.72±0.071	2.69±0.154	**2.734^{b}**
	A50	2.86±0.111	2.71±0.213	2.85±0.017	3.34±0.022	**2.93^{a}**
	A100	2.75±0.097	2.53±0.226	2.86±0.643	2.11±0.195	**2.501^{c}**
	Mean of groups	**2.726^{B}**	**2.888^{AB}**	**2.938^{A}**	-	-

C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); Means of duplicate ±SD (standard deviation); $^{A-B}$ Different the capital letters in the same row means significantly difference ($p<0.05$) between storage periods; $^{a-c}$ Different the small letters in the same column means significantly difference ($p<0.05$) between treatments.

TABLE 9.1. Mean squares and P-values (in parentheses) for total bacterial count (TBC) and fungal count.

Factor	df	Mean Square (p-value)	
		TBC	Fungal count
Treatment[1]	4	0.094(0.004*)	0.440 (0.000*)
Storage time[2]	3	0.174 (0.000*)	0.082 (0.108)
treatment × storage time	12	0.162 (0.000*)	0.224 (0.000*)

[1] Treatments: C: control sausage (with 100% fat and no additive), I: sausage with 0.34% inulin (replacing 1.99 % of fat content), A25: sausage with addition of 4.26% of artichoke bracts paste (which represent 25 % of fat replacement), A50: sausage with addition of 8.51% of artichoke bracts paste (which represent 50 % of fat replacement), A100: sausage with addition of 17.01% of artichoke bracts paste (which represent 100 % of fat replacement); [2] Storage time: 0,4,8, and 12 days; df: degrees of freedom; *Statistically significant at $P<0.05$

Conclusion

The comparison in this study between main wastes of globe artichoke (stem, bracts, and choke) was revealed that the bracts contain the highest amount polyphenols, flavonoids and has the highest antioxidant activity. Besides, artichoke bracts powder (ABP) is a good source of inulin. As a waste ABP consider as a promising healthy nutrient and could be conveniently used as a fat replacer during sausages processing. This incorporation caused a decrease in the added amount of fat, which decline the health issues related to fat content (obesity or cardiovascular diseases). Besides ABP addition improve cooking yield, decrease shrinkage without a significant change in sensory attributes especially in sample A25. Furthermore, ABP had considerable impact on TBC and fungal count. So, our recommendation is the use of the ABP as a fat replacer in different meat products.

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