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EVALUATION OF JERUSALEM ARTICHOKE AS A FUNCTIONAL INGREDIENT IN COOKIES PRODUCTION

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ABSTRACT

Jerusalem artichoke (JA) tubers are rich in minerals, fibers and inulin, a unique polysaccharide stored in them instead of starch. In this study, JA tubers were dried and ground into flour, which was then used to substitute 2.5, 5, 7.5 and 10% of wheat flour to prepare functional cookies using the previously mentioned functionality (minerals and fibers). The chemical composition of cookies was investigated, as well as the effects of substituting wheat flour for JA tubers flour (JAF) on it. JAF increased the moisture content of cookies, resulting in increased hardness and fractur ability. Fiber content increased as well, reaching a maximum of 0.8% at the highest substitution rate (10%). Ash content was increased from 0.6 to 1.09%, which was also related to the increased minerals (magnesium, calcium, phosphorus and iron), giving the prepared cookies high nutritional values. Physical properties of cookies including spread ratio, specific volume, and color showed marginal changes due to higher fiber and moisture contents in the prepared cookies. Furthermore, the sensory characteristics of JA cookies yielded satisfactory results, as overall acceptability was not significantly affected, although color was altered because of the pale or dark colored cookies at higher levels of substitution.

INTRODUCTION

Wheat flour, the main raw material in bakery products, is a good source of dietary energy and proteins but it is considered as poor **(Trethowan *et al.*, 2005)** in nutritional value. Bakery products are considered a main source of stable-food for human nutrition world-wide, dating back to ancient times **(Poole *et al.*, 2021)**. Cookies are a popular snack among kids, teenagers and even adults and the elderly. They are considered ready to eat products with an extended shelf life **(Kaur *et al.*, 2019)**. Cookies do not provide ~~a~~ high nutritional value to the extent that researchers have repeatedly held carried out investigations to enhance its nutritional value. Functional cookies were prepared by modifying the original cookie formula including the wheat flour substitution for; flaxseeds, sesame seeds **(Ertaş and Aslan, 2020)**, orange fleshed sweet potato **(Korese *et al.*, 2021)**, Spray dried and freeze-dried protein powders formed of sodium caseinate and blackcurrant concentrate **(Wu *et al.*, 2021)**, chia and quinoa seed flours **(Goyat *et al.*, 2018)**, moringa leaf powder **(Fapetu *et al.*, 2022)**, papaya pulp flour **(Varastegani *et al.*, 2015)** and nile tilapia bone powder **(Fong-in *et al.*, 2020)** and so many other materials in order to increase its nutritional value**.** One more reason for substituting wheat flour for other sources of flour is to reduce consumption of wheat flour due to the fact that, wheat suffers a global shortage. Egypt was reported by **FAO (2016)** to be the largest wheat-importing country worldwide **(Asseng *et al.*, 2018, Abdelmageed *et al.*, 2019)** .

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Jerusalem artichoke (JA), *Helianthus tuberosus* L., is a functional food ingredient as it contains inulin as the main polysaccharide that is stored in the plants' tubers instead of starch **(Singthong and Thongkaew, 2020)**. Inulin possesses various benefits for human health, it is a non-digestible polysaccharide that can only be decomposed through a fermentation process done by the large intestine's microbiota. Fermentation process that occurs to decompose inulin promotes and aids the growth of prebiotic bacteria, which is beneficial. Inulin can also increase the absorption of minerals in the large intestine, additionally, JA is a great source of minerals **(Munim *et al*., 2017).** JA is also known for its stomachic, tonic, diuretic, cholagogue, and aperient effects. Moreover traditional medicine had been used its tubers for the diabetic, rheumatism and some other applications for decades **(Shao *et al*., 2020).** JA is native to North America, but it was reported that, it can be widely adopted to diverse environments especially temperate areas, as the plant becomes naturalized **(Rossini *et al*., 2019)** and that is what happened to the Egyptian environmental conditions as the plant grew normally **(Moustafa *et al*., 2019)**.

JA tubers possess a number of bioactivity including high total dietary fibers, soluble dietary fibers, and insoluble dietary fibers of around 53.11, 40.07 and 13.04% respectively **(Singthong and Thongkaew, 2020)**; high mineral contents such as iron (0.4-3.7 mg/100g), sodium (1.8mg/100g), potassium (420-657mg/100g) and calcium (14-37 mg/100g) **(Ahmed and Rashid, 2019)**; high total phenolic compounds and antioxidant activity **(Singthong and Thongkaew, 2020)**, high contents of essential amino acids such as histidine, isoleucine, leucine, lysine, methionine, cystine, phenylalanine, tyrosine, threonine, tryptophan, and valine with arginine, asparagine, glutamine and alanine as the principle essential amino acids and a total protein contents of about 5.82-13.36% **(Méndez-Yáñez *et al*., 2022)** and considerable amounts of vitamin B complex and vitamin C **(Guo *et al*., 2018).**

In many studies, JA (leaves, stems and tuber powder) was added to the bakery products (bread muffins, crackers, cake, and other products) and dairy products including low-fat yoghurt. The addition of JA had no effects on sensory characteristics, as it does not have an off-flavor and it can reduce the glycemic index and increase the nutritional value of these products, as well as possess many other health benefits **(Çetin Babaoğlu *et al*., 2021; Ceylan *et al*., 2021; Méndez-Yáñez *et al*., 2022)**.

The aim of this study was to exploit the benefits of JA in the preparation of functional cookies by substituting wheat flour for JA flour at levels of 2.5, 5, 7.5 and 10%. This study also aimed at investigating the effects of JA partial substitution on the chemical composition, minerals contents, physical properties, and sensory characteristics of the prepared cookies.

MATERIALS AND METHODS

Materials

All materials, including commercial wheat flour (Al-Duha) (72% extraction rate) with 11.5% protein (N x 5.7), 13.89% moisture, 1.7% fiber, 0.66% ash, baking soda, eggs, salt, sugar, and other cookies' formula materials were all purchased from the local market in Zagazig city, Sharkia Governorate, Egypt. JA tubers were obtained from the Horticulture Research Institute, Agricultural Research Center, Giza, Egypt. All chemicals used were of analytical grade and purchased from El-Gumhorya Company; reagents were purchased from Sigma-Aldrich (Germany).

JA Flour (JAF) Preparation

JA tubers were cleaned to exclude stones, untypical or infected tubers, and any other foreign bodies. Tubers were then washed using tap water to remove dust and mud, dried using towels, cut into thin slices to affirm a faster drying rate, and dried at 40-50℃ for 72 hours, flipping every 8 hours to avoid rotting. Dried tubers' slices were then ground in a laboratory mill, and the resulting powder was then passed through a 60 mesh sieve to assure uniformity. The sieved fine powder obtained from JA tubers (referred to as JA flour) was then vacuum sealed in bags and stored in freezer until further use.

Cookies Preparation

Cookies without and with the wheat flour substitution for JAF were prepared using the modified **AACC 10-50D (2002)** method with modifications as dextrose solution "which was added to aid brown coloring" in the original method was not added because JAF has a darker color compared to wheat flour. The substitution of wheat flour for JAF is presented in Table 1. To accommodate the mixer loading capacity, the cookies formula was fixed to all samples (1375g flour, 250ml milk, 250g sugar, 500g fat, 2.5 NH_4Cl and two whole eggs). Shortening and sugar were mixed thoroughly to get a soft cream. The mixture was mixed at low speed for 3 minutes and scraped down after each minute. Water was then added and mixed for 1 minute at low speed. Dry ingredients and the whole eggs were then added to the creamy mass and mixed to a homogenous mass for two minutes at low speed, scraping down every 30 seconds. The dough was scraped from the bowl and placed on a lightly greased cookie sheet. The prepared dough was sheeted to a thickness of 7 mm and cut using a 60mm diameter cookie cutter. Cookies were baked at 205°C for 11 min.

Baking experiment was done in Al-Rhehab bakery in Zagazig City, Sharkia Governorate, Egypt. The prepared cookies without the JAF (control sample) and with JAF are presented in Fig. 1.

Chemical composition of raw materials, control and JAF cookies

Moisture contents of raw materials, control cookies and cookies prepared with the partial substitution of wheat flour with JAF were determined by the forced air oven according to the **AACC 44-15A (2010)** method using the one-stage method because the moisture contents of the samples did not exceed 13%. Ash, fat, fibre, protein and carbohydrates were all measured using the AOAC's official method **(AOAC, 2005).**

A comparison between the chemical composition of JAF and wheat is presented in Table 2. JAF contained lower percentages of moisture, fat and protein contents (7.82, 0.53 and 4.27% compared to the respective values in wheat flour (11.79, 0.66, 11.37%). Ash and fibre contents of JAF (5.27 and 3.95%) were higher than those of wheat flour (1.54 and 1.88%).

Mineral Contents of Control and JAF Cookies

Minerals contents of cookies without and with the partial wheat flour substitution with JAF were determined according to the method described by **Mouminah (2015)**. Wet acid digestion was performed on the samples using 5:1 *W/V* mixture of nitric acid and perchloric acid. The total amount of minerals in the digested samples was determined by Thermo-Elmental, Model 300VA, UK, 1969 **(Hamed and Mouminah, 2015)**.

Physical Properties of Control and JAF Cookies

Physical properties of cookies without and with JAF substitution were analyzed for spread ratio, specific volume, texture and color.

After cookies baking, cookies were allowed to cool to room temperature before being stored in airtight polythene bags for further investigations. Thickness, diameter, and spread ratio were measured 30 min after removing the cookies from the oven.

Table 1. Wheat flour substitution for JAF

Treatment	Wheat flour (g)	JAF** (g)
Ctrl *	1000	0
JAF2.5	975	25
JAF5	950	50
JAF7.5	925	75
JAF10	900	100

Where, ctrl* is the control treatment and JAF** is the Jerusalem artichoke flour

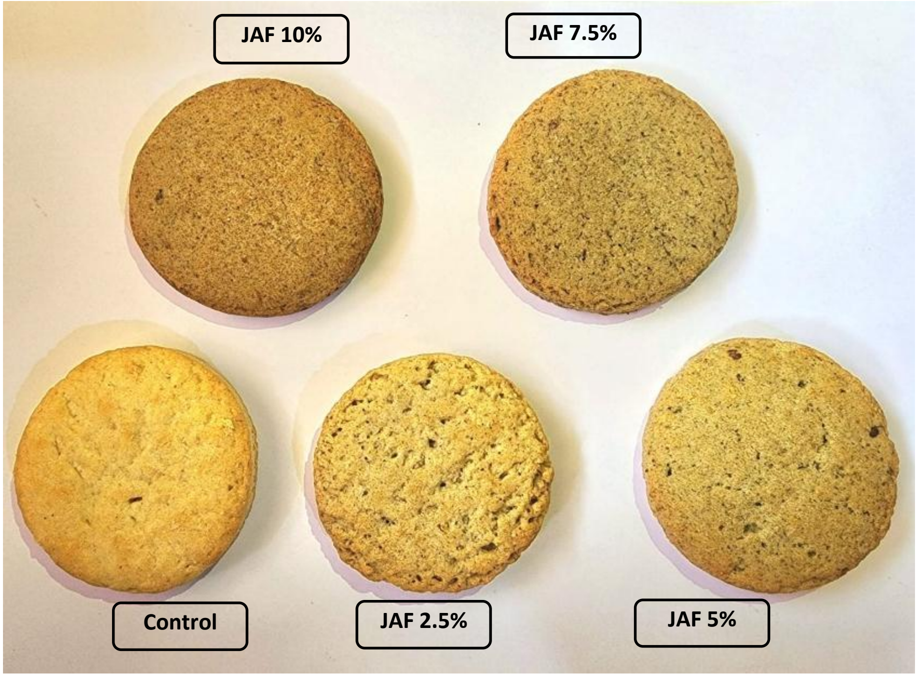

Fig. 1. Cookies samples including control cookies, JAF 2.5, 5, 7.5 and 10%

Table 2. Some chemical composition of Jerusalem artichoke compared to wheat flour

Parameter (%)	Jerusalem artichoke flour	Wheat flour
Moisture	7.82	11.79
Ash	5.27	1.54
Fat	0.53	0.66
Protein	4.27	11.37
Fiber	3.95	1.88

Cookies were measured for their specific volume according to the method described by **Lauková *et al*. (2016)**. Cookies were weighted and the volume was measured by rapeseed displacement, then volume was divided by weight to calculate the specific volume.

As for measuring of cookies' texture, a three-point bend test was made on six cookies using a texture analyzer (Brookfield CT3-4500 (AMETEK, Middleborough, MA, USA)) equipped with a load cell of 10 Kg, TA-AACC36 cylinder, a trigger load of 0.07N, pretest speed of 2 mm/sec, test speed of 2 mm/sec, return speed of 2 mm/ sec, a number of cycles is 2 and a data rate of 100 points/s **(Barragán-Martínez *et al*., 2022)**.

Color Values of Control and JAF Cookies

Color values of cookies without and with the partial wheat flour substitution for JAF were determined according to the method of **Abdel-Samie *et al*. (2010)** using a chromameter (CR-400, Konica Minolta-Sensing, Japan). Color was determined as L^*, a^*, and b^* values, with L^* value represents lightness (brightness), a^* value represents redness (where $+a^*$ is redness while $–a^*$ is greenness), and b^* value represents yellowness ($+b^*$ is yellowness while $–b^*$ is blueness). A white-colored calibration plate No. 20533051 (x = 94.0, y = 0.3158, and z = 0.3322) was used to calibrate the machine between every two measurements. Two replicates of every sample were analyzed, and average was reported. Six measurements per cookie sample were measured and the results were reported as the average plus or minus the standard deviation of the replicates.

Sensory Evaluation of Control and JAF Cookies

Sensory-evaluation analysis of cookies prepared with or without the partial substitution of wheat flour for JAF was carried out with the help of 50 panelists. Panelists received samples encoded in a three digits code without any arrangement of levels or any special numbers to avoid bias for or against a specific sample. Panelists were asked to evaluate the prepared cookies for sensory parameters including color, texture, flavor, and aroma based on a twenty-point hedonic scale , and the sum of them was named as over-all acceptability, according to the following scoring system: 2- dislike extremely; 10- neither like nor dislike; and 20- like extremely. Sensory evaluation of cookies provides a practical and rapid test of quality in the absence of direct methods to measure taste and aroma. The results obtained from the sensory evaluation test enable the evaluation of food and help to judge consumer acceptance without following detailed chemical or microbiological methods **(Abdel-Samie, 2013)**.

Statistical Analyses

All the experimental data are presented as mean values plus or minus the standard deviation of the mean of the replicates of the individual samples. Data were analyzed for significance using the SPSS 17.0 statistics program, with a one-way analysis of variance (ANOVA) performed at the significance level of 0.05%. Duncan's multiple range test was used to differentiate between mean values, and the standard deviation was calculated using the same software.

RESULTS AND DISCUSSIONS

Chemical Composition of Cookies

The approximate chemical composition of cookies prepared without and with the substitution of wheat flour for JAF (named as Control, JAF2.5, JAF5, JAF7.5 and JAF 10%) is presented in Table 3. Moisture contents did not show pronounced changes as the control, JAF2.5, JAF5, and JAF7.5 showed no significant differences ($p \leq 0.05$), while only JAF10 statistically showed increased moisture contents with an increase

Table 3. Effect of wheat flour substitution using Jerusalem artichoke flour on the chemical composition of cookies

Treatment	Chemical composition (% based on dry weight)					
	Moisture	Fiber	Ash	Protein	Fat	Carb** (by differences)
Control	4.83*[b]	0.33[d]	0.60[d]	8.27[a]	29.33[a]	61.48[a]
JAF2.5	5.26[ab]	0.48[c]	0.73[cd]	7.87[b]	29.11[a]	61.82[a]
JAF5	5.72[ab]	0.58[bc]	0.86[bc]	7.73[bc]	29.06[a]	61.78[a]
JAF7.5	6.12[ab]	0.69[ab]	1.01[ab]	7.51[cd]	29.05[a]	61.76[a]
JAF10	6.35[a]	0.80[a]	1.09[a]	7.33[d]	29.07[a]	61.72[a]
LSD at 0.05	1.308	0.130	0.172	0.267	0.597	0.658

*Mean (n = 3) ± standard deviation. Means in the same column followed by the same superscript letters are not significantly different ($P \leq 0.05$). ** is carbohydrates.

percentage of around 13.5% compared to the control sample which scored 4.83% of moisture content. Higher moisture contents in the JAF cookies samples might be because of the higher fiber contents in JAF (3.95% compared to 1.88% in wheat flour (Table 2). These findings were also found by **Nakov *et al.* (2020)** who reported a progressive increase in moisture contents in apple pomace added cookies because of their high fiber content that had strong binding properties with water. As a result of the higher fiber contents in JAF, fiber contents in cookies samples showed proportional increase with the gradual increase in the substitution level of wheat flour for JAF. The minimal fiber percentage was that of the control cookies samples (0.33%), compared to the higher fiber percentages of 0.48, 0.58, 0.69 and 0.8% in JAF2.5, 5, 7.5 and JAF10% respectively. Ash contents of JAF2.5, 5, 7.5 and JAF10% cookies samples showed significantly ($p \leq 0.05$) higher values (0.6, 0.73, 0.86, 1.01 and 1.09% respectively) compared to the minimal ash contents in control sample with a score of 0.6%. Lower protein contents in JAF as shown in Table 2. caused a gradual dilution in protein contents in cookie samples but the change was not significant ($p \leq 0.05$). Carbohydrates contents in cookies of different formulas did not have any significant differences ($p \leq 0.05$) **(Nakov *et al.*, 2020)**.

Mineral Contents of Control and JAF Cookies

It is repeatedly reported that, JA tubers contain considerable amounts of minerals **(Ahmed and Rashid, 2019)**. And as it was also shown from Tables 2 and 3, that, the ash contents of JAF and JAF containing cookies are higher than the ash contents of wheat flour and control cookies. Minerals content in cookie with the substitution of wheat flour for JAF contained significantly ($p \leq 0.05$) higher mineral contents compared to the mineral contents of control cookies samples (Fig. 2). Magnesium contents of control cookies samples were 42.56 mg/ 100 g and substituting 2.5, 5, 7.5 and 10% of wheat flour with JAF increased magnesium contents by 23.1, 43.9, 53.6 and 67.2% of the original contents in control cookies to reach maximal value in JAF10 at a score of 71.15mg/100g. Calcium is most abundant element in human body, and it aids the maintenance of bone and teeth.

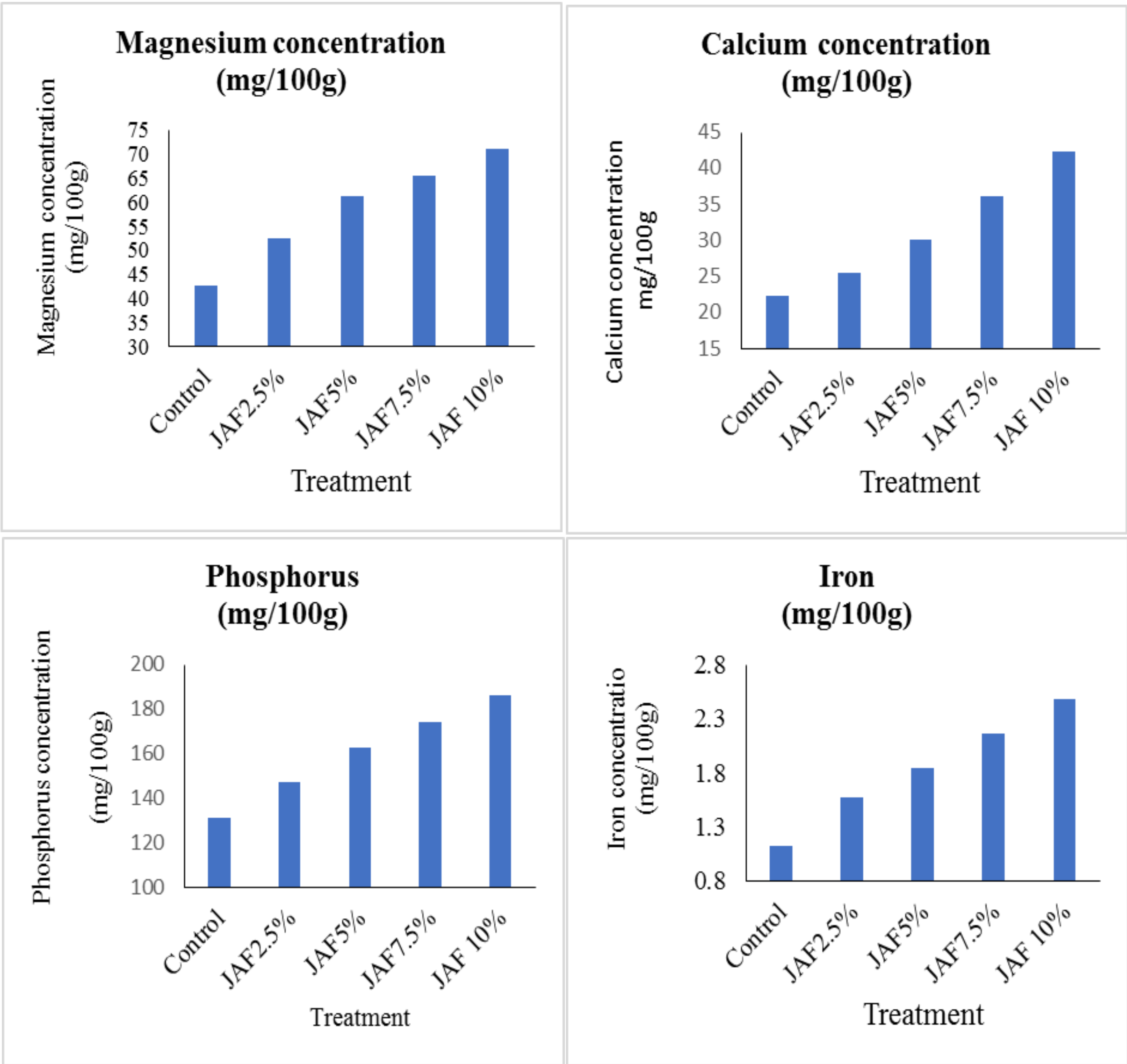

Fig. 2. Mineral contents in cookies without and with wheat flour substituted with JAF in 2.5, 5, 7.5, and 10%

Calcium contents in JAF substituted cookies increased by 14.1, 53.3, 61.8, and 89.6% of the original magnesium content in control cookie samples (22.34mg/100g), with a maximal value scored by JAF10 at 42.35 mg/100g. Phosphorus contents in control cookies was 131.0mg/100g, and it increased by 12.6, 24.0, 32.8 and 42.4% of the original contents in control cookie samples to reach a maximal value of 186.5 mg/100 g in JAF10. Iron has several functions in human body such as participating in carrying oxygen to the muscles as haemoglobin structure, and many other benefits. Iron as well, showed a significant increase in JAF cookies which showed 38.9, 63.7, 91.2 and 119.5 increase percentages comparing to iron contents in the control sample which scored 1.13 mg/100 g and the highest value was also shown by the JAF, which scored an iron content of 2.48 mg/100 g.

JAF cookies showed significantly (*p≤ 0.05*) higher contents of all investigated minerals, including magnesium, calcium, phosphorus, and iron which makes it of a potential application in the enrichment of cookies in minerals to making it an added value in functional cookies production. JAF was also reported by **Rushchitc *et al*. (2022)**, to increase the minerals content in dumpling dough, including calcium and iron, which were 3.9 and 7.48 times higher than wheat flour.

Physical Properties of Cookies

Physical properties of cookies prepared with and without the substitution of wheat flour with JAF at different levels are presented in Table 4. Gradual proportional substitution of wheat flour for JAF caused proportional increase in–cookie's diameter from 6.57 cm for the control cookie samples (minimal value) to reach a maximal value (7.39 cm) in the JAF10. The low diameter in control cookie samples may be attributed to the relatively higher contents in protein, especially gluten which is the main protein in wheat flour that can hold the structure against spread. Proportional increase in JAF percentage caused a dilution of gluten and caused a weaker gluten network that was less successful in holding dough against spread. These results are in line with the results of **Mohamad Nor *et al*. (2021)** who substituted wheat flour with a gluten free component (sweet potato) and noted increased diameter values with the increased substitution level. A gradual decrease in thickness was also noted with the increase in substitution level, as the maximal thickness value was that of control cookie samples (1.56cm) and minimal thickness value was that of JAF10 cookies (1.24 cm). The lower thickness values in the JAF cookies might be because of the higher diameter values. As a result of the increased diameter and decreased thickness values, the proportional increase of JAF percentage led to an increase in spread ratios. Spread ratio of control cookies scored 4.21and that was the lowest value, and substitution of 2.5, 5, 7.5 and 10% of wheat flour for JAF significantly (*p≤0.05*) increased the spread ratio to become 4.41, 4.76, 5.09 and 5.9, respectively.

Gluten dilution with the substitution of wheat flour for gluten-free JAF caused relatively lower values regarding specific volume because the gluten can give volume to cookies **(Nakov *et al*., 2021)**. The specific volume of control samples was maximal (1.84) while JAF samples were significantly (*p≤0.05*) lower (1.72, 1.63, 1.63 and 1.55 in the 2.5, 5, 7.5 and 10 wheat flour substitution levels, respectively).

The color values of cookies without and with the substitution of wheat flour for JAF were presented as *L**, *a**, and *b** values (Table 4). A significant (*p≤0.05%*) decrease in the lightness of cookies was noted with the gradual increase in the substitution level of wheat flour for JAF, which means that JAF cookies were darker than control cookies. This might be because of the dark color of JAF compared to the ultra-white colored wheat flour, which was in line with the results of **Awobusuyi *et al*. (2020)**, who reported darker cookies with the increased use of the darker color additive (sorghum–termite blend). The redness (*a**) and yellowness (*b**) of the cookies decreased as the JAF percentage increase which had an impact on the coloration of the cookies that was pale compared to the golden colored cookies prepared without the presence of JAF. The less coloration of JAF cookies might be because of the dilution effect of Maillard reaction's substrates (reducing sugar and the amino acid asparagine) which is not found in JAF and found in wheat flour. These findings are similar to those found by **Ceylan *et al*. (2021)** who reported a decrease in the *L** and *b** values of cake prepared with the addition of JAF.

Table 4. Physical properties (spread, specific volume, and color values) of control and JAF cookies

Treatment	Baking quality			Specific volume			Color values		
	Diameter (cm)	Thickness (cm)	Spread ratio	Weight (g)	Volume (mm)	Specific volume	*L**	*a**	*b**
Control (5)	6.57*d	1.56a	4.21^{e}	28.42^{a}	52.20^{a}	1.84^{a}	68.14*^{a}	8.43^{a}	26.01^{a}
JAF2.5	6.78c	1.54a	4.41^{d}	25.68^{c}	44.16^{b}	1.72^{b}	60.35^{b}	5.23^{b}	21.73^{b}
JAF5	7.13b	1.49b	4.75^{c}	24.84^{c}	40.56^{c}	1.63^{c}	51.94^{c}	4.54^{c}	18.67^{c}
JAF7.5	7.31a	1.43c	5.09^{b}	25.22^{c}	40.95^{bc}	1.63^{c}	46.92^{d}	3.33^{d}	16.97^{d}
JAF10	7.39a	1.24d	5.90^{a}	26.97^{b}	41.80^{bc}	1.55^{d}	38.05^{e}	2.58^{e}	13.76^{e}
LSD at 0.05	0.070	0.011	0.058	0.935	3.328	0.037	3.965	0.497	1.279

*Mean (n = 3) ± standard deviation. Means in the same column followed by the same superscript letters are not significantly different ($P \leq 0.05$).

Textural Characteristics of Control and JAF Cookies

Results pertaining to the texture characteristics of JAF and control cookies are presented in Table 5. Hardness at the first and second cycle of the test of control cookies were higher than all other samples at a score of 7.9 and 5.06N, respectively. Hardness decreased to reach its minimum score in JAF5 (3.03 and 1.0N, respectively at the first and second cycle of the test, respectively). Lower hardness might be attributed to the dilution of the gluten network by the substitution of the gluten rich component (wheat flour) for the gluten free component (JAF). This explanation is in accordance with **Hussain *et al*. (2020)** who reported a reduction in the hardness of cookies with the incorporation of low-gluten or gluten-free additives. At the higher additional levels of JAF (7.5 and 10%), hardness increased again compared to JAF 2.5 and 5%, but not as much as in control samples. This increase could be attributed to the higher fiber contents, which could retain more moisture (see Table 3), allowing starch to gelatinize more than in lower moisture content cookies, potentially increase cookies' hardness **(Hasan *et al*., 2020)**. The same behavior of changes that was noted in the hardness of cookies was obtained in the whole texture profile as all textural characteristics (adhesive force, adhesiveness, fracturability, cohesiveness, springiness and springiness index, gumminess, chewing and chewing index) decreased from their maximal value (control sample) to reach the minimum values in the JAF 5.0%, then increased again to higher values compared to the 2.5 and 5% of the JAF, but not equal to the control samples.

Sensory Evaluation of Control and JAF Cookies

Table 6 shows the effect of the partial substitution of wheat flour for JAF at different levels (2.5-10%) on the sensory characteristics of cookies. It is noted that for consumer preference, the colour of cookies was strongly affected by the partial substitution of wheat flour for JAF as colour scores of control cookies were maximal at an average score of 18.3 and the colour scores decreased proportionally to reach a minimal score (11.0) for JAF10%. The Same trend of effects were observed in the colour and aroma scores, with control cookies achieving the highest scores (18.0) and JAF cookies achieving lower scores with a minimal score (17.0) for JAF10.

Table 5. Texture profile of control and JAF cookies

Texture parameter	Treatment				
	Control	JAF2.5	JAF5	JAF7.5	JAF10
Hardness cycle 1 N	7.90	4.31	3.03	3.93	7.64
Hardness Cycle 2 (N)	5.06	0.79	1.0	1.62	3.16
Adhesiveness force (N)	0.23	0.10	0.12	0.1	0.12
Adhesiveness (g.cm)	3.00	1.00	1.0	1.0	2.00
Fracturability (N)	7.71	4.21	2.9	3.81	7.34
Cohesiveness	0.11	0.06	0.03	0.12	0.10
Springiness (mm)	3.90	3.21	2.48	2.78	3.13
Springiness index	0.49	0.41	0.32	0.36	0.40
Gumminess (N)	0.87	0.26	0.09	0.46	0.96
Chewiness (g.cm)	34.00	19.00	12.00	13.0	31
Chewiness index (N)	0.42	0.11	0.13	0.17	0.38

Table 6. Effect of wheat flour substitution using Jerusalem artichoke flour on sensory evaluation of cookies

Treatment	Sensory evaluation					
	Color (20)	Aroma (20)	Texture (20)	Crispness (20)	Taste (20)	Overall acceptability (100)
Control (5)	18.30^{a}	18.00^{a}	16.00^{b}	15.30^{c}	17.29^{a}	84.89^{a}
JAF2.5	16.00^{ab}	17.60^{a}	17.67^{ab}	16.60^{bc}	18.33^{a}	86.20^{a}
JAF5	14.65^{bc}	17.40^{a}	18.67^{a}	17.30^{ab}	18.67^{a}	86.69^{a}
JAF7.5	12.35^{cd}	17.20^{a}	18.67^{a}	17.65^{ab}	18.00^{a}	83.87^{a}
JAF10	11.00^{d}	17.00^{a}	19.31^{a}	18.33^{a}	18.00^{a}	83.64^{a}
LSD at 0.05	2.406	2.504	1.837	1.553	2.084	5.935

*Mean (n=50) ± standard deviation. Means in the same column followed by the same superscript letters are not significantly different (P≤0.05).

These changes might be attributed to the relative dilution of Maillard reaction components (asparagine and reducing sugars) when wheat flour was substituted for JAF in increasing percentages. Alternatively, JAF cookies outperformed the control cookies in all other sensory attributes, including texture, crispiness, and taste. Overall acceptability of cookies showed no significant differences (*P≤0.05*) between different types of cookies, making JAF a potential application that does not affect the sensory characteristics of cookies when added up to 10%.

Conclusion

Jerusalem artichoke tubers flour (JAF) was used to substitute 2.5, 5, 7.5 and 10% of wheat flour to prepare functional cookies. Moisture contents of the prepared cookies (using JAF) were higher than the control, which also reflected increased hardness and fracturability. Fiber contents also increased, and ash contents also increased from 0.6 to 1.09% which was also reflected in an increased mineral (magnesium, calcium, phosphorus and iron), which give the prepared cookies high nutritional values. Physical properties, texture profile and sensory evaluation investigations showed satisfactory results making JAF of a potential application to enrich the functionality of cookies.

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الملخص العربي

تقييــــم الطــرطــوفـــة كمكـــون وظيفي في تحضير الكوكيز

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درنات الطرطوفة غنية بالمعادن، الألياف، وتحتوي على كميات معتبرة من الأنيولين والذي يعتبر سكر عديد مميز للنبات حيث يخزن في الدرنات بدلا من النشا. في هذه الدراسة، جففت درنات الطرطوفة وتم تحويلها الى دقيق وتم استبدال ٢,٥، ٥، ٧,٥ و١٠% من دقيق القمح بدقيق درنات الطرطوفة لتحضير كوكيز وظيفية مرتفعة المحتوى من المعادن والألياف. أيضا تمت دراسة التركيب الكيميائي للكوكيز وأيضا تأثير استبدال دقيق القمح باستخدام دقيق درنات الطرطوفة على مختلف الخصائص. تسبب دقيق درنات الطرطوفة في ارتفاع المحتوى الرطوبي للكوكيز والذي نتج عنه زيادة في صلابة والقوة اللازمة لتكسير الكوكيز. زاد ايضا محتوى الكوكيز من الالياف لتصل الى اعلى مستوى (٠,٨%) في اعلى نسبة استبدال لدقيق القمح بدقيق الطرطوفة (١٠%) زاد الرماد من ٠,٦ الى ١,٠٩% مرتبطا بزيادة العناصر المعدنية (الماغنيسيوم، الكالسيوم، الفوسفور، والحديد) مما يعطي الكوكيز المنتجة باستخدام دقيق درنات الطرطوفة قيمة غذائية أعلى من معاملة الكنترول. أظهرت الخصائص الفيزيائية مثل نسبة الافتراش، الوزن النوعي، واللون، تغيرات نوعية وذلك يمكن ان يكون راجعا لمحتوى دقيق درنات الطرطوفة من الالياف والمحتوى الرطوبي المرتفع المدمص في الكوكيز المنتجة. أيضا أظهرت نتائج التقييم الحسي ان إضافة دقيق درنات الطرطوفة كانت مقبولة للمقيمين الحسيين حيث أن القبول الكلي لم يتأثر بالرغم من تأثر قيم اللون واكتساب الكوكيز لونا شاحبا غامقا في أعلى نسب استبدال.

الكلمات الاسترشادية: الطرطوفة، الكوكيز الوظيفية، رفع محتوى العناصر المعدنية، رفع محتوى الألياف.

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