Potential Effects of Mixing Plant Parts on the Chemical, Rheological and Sensory Properties of Free-Gluten Products

التأثيرات المحتملة لخلط أجزاء نباتية على الخواص الكيميائية والريولوجية والحسية للمنتجات الخالية من الجلوتين

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ABSTRACT

The current study aims to investigate the potential effect of mixing plant parts i.e. carrot (CP) and sweet potato (PP) powders on the chemical composition, minerals content, rheological properties, and sensory evaluation of free-gluten bakery products that are suitable for celiac or gluten-sensitivity patient. For this purpose, three different concentrations 10, 20, and 30% of plant parts (CP or PP) were added as a substitution for rice flour (RF), corn flour (CF), and the flour mixture (50%RF+ 50%CF). The obtained results of the chemical composition showed that the partial replacement of RF, CF, and the flour mixture RF+CF with different percentages (10, 20, and 30%) of CP led to an increase in moisture 3.79%, 2.42% and 3.06%, crude fiber 35.28%, 47.11% and 49.83% , and ash 36.23%, 39.39% and 37.77% and a decrease in total protein -15.34%, -19.36% and -17.72%, and crude fat-8.95%, -19.45% and-15.94%.While that, replacement of RF, CF, and the flour mixture RF+CF with different percentages of 10%, 20%, and 30% of PP led to an increase in crude fiber 11.07%, 8.01% and 9.30%, ash 34.05%, 37.12% and 35.55%, and carbohydrates 1.83%, 4.13% and 2.95%, and a decrease in moisture -4.17%, -5.19% and -4.73, total protein -19.82%, -22.53% and -21.39%, and crude fat -18.90%, -24.43% and -22.59%. For mineral compositions, substitution of the same ratios of CP led to an increase in both K5.58%,77.14% and 23.42%, Na 34.11%, 20.37% and 26.41%, and Ca 1.62%, 7.89% and 4.50%, which was met at the same time with a rate of decrease in P -25.32%, -17.81%, and -23.24% and Fe -9.93% -6.13% and -8.36% compared with all control samples (RF, CF, and RF+CF). The replacement of RF, CF, and the flour mixture RF+CF with three levels of PP led to an increase in K 23.14%, 130.0% and 49.77% and Ca 47.75%, 63.15% and 54.78%, and a decrease in P-22.26%, -9.84% and -18.82%, Fe-7.37%, -3.06% and -5.57%, and Zn-26.26%, -8.10% and -23.62%. Rheological properties of corn flour that partially replaced with 10, 20, and 30% of CP and PP showed a decrease in water absorption, arrival time, dough development time, dough stability, farinograph quality number, extensibility, relative resistance to extension, proportional number, and energy compared with the control (unsubstituted corn flour). Finally, sensory evaluation findings showed an acceptance of crackers produced from corn flour and substituted with 10%, 20%, and 30% CP and PP. In conclusion, the data of the present study confirms the possibility of adding plant parts (carrot and sweet potato powders) to produce free-gluten products that reduce the risk of celiac disease or gluten sensitivity.

Key Words: carrot powder, sweet potato powder, rice flour, corn flour, minerals content, celiac disease**.**

INTRODUCTION

Celiac disease (CD) is an autoimmune illness caused by the interplay of environmental, genetic, and immunological factors. It is a persistent digestive condition. In genetically sensitive individuals, autoantigen creates permanent sensitivity to gluten, environmental variables, and inflammatory lesions. This condition is characterized as an anomaly in the intestinal mucosa that improves morphologically when treated with a gluten-free diet but worsens when gluten is reintroduced. Non-tropical sprue and gluten-sensitive enteropathy are other names for it. Due to the harmful action of gluten, which destroys the villi of the small intestine, this condition is associated with poor digestion and absorption of nutrients such as vitamins and minerals in the gastrointestinal system **(Tamai & Ihara, 2023 and Gromny & Neubauer, 2023).** CD is a systemic disease that does not only affect the gastrointestinal tract. Extraintestinal manifestations can affect practically all organs, with varying degrees of severity, including the neurological system, liver, reproductive system, skin, cardiovascular system, and musculoskeletal system. Untreated CD can cause gastrointestinal adenocarcinoma and lymphoma of the small intestine in some people. A stringent gluten-free diet can help reduce disease-related problems. Some of these manifestations arise in childhood, whereas others do not appear until adulthood or even old life. There are three types of malabsorption: classical (diarrhea, steatorrhea, weight loss, or failure to thrive), non-classical/oligosymptomatic (individuals present without signs and symptoms of malabsorption), and extraintestinal **(Assa *et al*., 2017; Laurikka *et al*., 2018 and Graça *et al*., 2020).**

Gluten-free products have become increasingly popular due to the growing demand for gluten-free options, as about 1% of the world's population suffers from gluten intolerance. So, people diagnosed with celiac disease must avoid consuming gluten-containing products to avoid symptoms of the disease (**Kırbaş *et al*., 2019).** On the other hand, consuming more vegetables can help lower the incidence of nutrition-related chronic diseases such as CD, which is currently a major public health problem. Vegetable byproducts and wastes are rich in bioactive substances like dietary fibers and phenolic compounds that have antibacterial, cardioprotective, and anticancer properties. It has high levels of polyphenols and dietary fibers **(Anal, 2017 and Badjona *et al*., 2019).** Rice (*Oryza sativa*) is high in nutritional nutrients like carbs, vitamins, and minerals. It provides around 21% of the ingested energy and 15% of the consumed protein for communities that rely on it as a staple diet **(Gondal *et al*., 2021).** Because of its hypoallergenic protein, soft taste, and white color, rice flour has been frequently recommended as an alternative for creating gluten-free breads (GFB) **(Graça *et al*., 2020).** Maize (*Zea mays*) has the biggest global output of any grain crop. Maize is a significant source of starch. Maize flour is a common ingredient in both home cooking and many manufactured foods. Corn, particularly yellow types, is also higher in vitamin A and ash content. It contains a lot of calories, carbs, protein, potassium, sodium, chlorine, and sulfur. When taken as a whole, corn protein is still low in lysine, very low in tryptophan, and fair in sulfur-containing amino acids like methionine and cysteine. Corn contains just leucine and aromatic amino acids, phenylalanine, and tyrosine **(Kumar *et al*., 2021).**

Carrot (*Daucus carota*) consumption will assist in alleviating vitamin A insufficiency in youngsters on a broad scale, which is critical in today's lifestyle. A carotenoid-rich diet may protect against numerous types of cancer, reduce cholesterol levels, and aid in weight loss **(Lothe *et al*., 2019 and Trilokia *et al*., 2022).** Carrots can successfully be utilized to improve various functional qualities in a variety of deficit diets. Carrot fiber helps to maintain a healthy body weight and lowers the risk of hypertension, coronary heart disease, stroke, type 2 diabetes, obesity, and other metabolic syndromes. Furthermore, the pectin in carrots exists as calcium pectate, which can help lower cholesterol levels (**Nasir *et al*., 2020).** Sweet potato (*Ipomoea batatas* L.) is employed because of its nutrients and antioxidant chemicals, as well as its unusual color, flavor, and fragrances, which have the potential to be natural enhancers of these properties. Sweet potatoes are high in carbs, minerals, and vitamins, as well as amino acids such as aspartic and glutamic acid and proline and antioxidants including phenolic acids, anthocyanins, tocopherol, and -carotene. Sweet potato flour contains maltose, sucrose, fructose, glucose, and raffinose **(Pereira *et al*., 2019; Thriveni *et al*., 2019 and Ndife *et al*., 2020).** For all the above reasons, adding these plant parts to food products, such as gluten-free products, will be of great importance to users of those products. Therefore, the present study was carried out to investigate the potential effects of mixing plant parts (carrot and sweet potato powders) on the chemical, nutritional, rheological and sensory properties of free-gluten products.

MATERIALS AND METHODS

Materials

- Plant parts (carrot roots and sweet potato tubers) were obtained from the local market, New Damietta City, Damietta Governorate, Egypt.
- Bakery products ingredients include egg, vanilla, baking powder, butter, dry yeast, salt, sugar, skim milk powder, corn oil) obtained from the local market, and corn flour and rice flour were obtained from El Forat for food industries, Damietta City, Damietta Governorate Egypt.
- Chemical includes all bioactive compounds standards [gallic acid, rutin, tannic acid], α-tocopherol, butylated hydroxy toluene (NHT) were purchased from Sigma Chemical Co., St. Louis, MO. Other chemicals except mentioned elsewhere, organic solvents and buffers were obtained in analytical grade from

El-Ghomhorya Company for Trading Drugs, Chemicals, and Medical Instruments, Cairo, Egypt.

– Machines: absorbance (Abs) for different determents was measured using Labo-med. Inc., spectrophotometer, CA, USA. Atomic absorbance, Schematzu apparatus, Tokyo, Japan using for elements determination. Farinograph instrument (Brabender Duis Bur G, type 810105001 No. 941026, Germany. Extensograph (Barabender Duis Bur G type 860001 No. 946003, Germany.

Methods

Preparation of carrot and sweet potato powder

Sweet potato and carrot powders were prepared and treated according to the method described by **Hutasoit *et al*. (2018)**. The cleaned roots were peeled manually with a stainless-steel kitchen knife and sliced into 2 mm-thickness with the use of an electrical chipping machine. The chips were dipped in aqueous 0.5 and 1.0% citric acid, followed by steam blanching for 30 minutes. The treated chips carrots and sweet potatoes were dried using a convection oven at 55 ℃ for 12 hours. The flour (moisture content about 10%) was obtained by milling the dried slices using a high mixer blender (Toshiba Elaraby, Damietta, Egypt) into flour with a particle size of about 200 µm, and the resulting flour was sieved to obtain a fine. The flour was then packaged in polyethylene bags and kept in a freezer at -20 °C for further physical and chemical analyses as well as use in products preparation.

Chemical analysis

Moisture, protein, fat, crude fiber and ash were determined for rice flour (RF), corn flour (CF), and the flour mixture (50%RF +50%CF), carrot powder (CP), and sweet potato powder (PP) as described in **A.O.A.C. (2005),** while total carbohydrates were calculated by the differences.

Carbohydrates (%) = [100 – (moisture + fat +protein +crude fiber +ash)]

Determination of minerals content

Minerals content of corn, rice flour, and the flour mixture (50%RF +50%CF), carrot and sweet potato powder were determined according to the method mentioned by **Singh *et al.*, (1991)** as follow: half gram of defatted sample were transferred into a digested glass tube and 6 ml of tri-acids mixture (nitric acid: perchloric acid: sulfuric acid in the ratio of 20: 4: 1 v/v respectively) were added. The tubes content were digested gradually as follows: 30 min at 70 0C; 30 min at 180 0C and 30 min at 220 0C. After digestion, the mixture was cooled, dissolved in distilled water, and the volume was increased to 50 ml in a volumetric beaker. After filtration in ashless filter paper, aliquots were analyzed for minerals Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Phosphorous (P), Iron (Fe), and Zinc (Zn) using an atomic absorption spectrophotometer (Shimadzu Corporation, Tokyo, Japan).

Rheological parameters

Farinograph test

A farinograph instrument was used to determine the water absorption and mixing characteristics of dough corn flour from the various blends of 10, 20 and 30% carrot and sweet potato powder. The following parameters were obtained from the farinograms except the percentage of water absorption which was recorded directly from the farinograph instrument as described in the **A.A.C.C. (2000).** Farinograph tests were performed to study the hydration and mixing characteristics of the dough under investigation. About 300 g of tested flour were placed in the bowl of the apparatus and sufficient water was added so that the consistency of the dough was such that the mixing curve was centered on the 500 Brabender units (B.U.) line to the point of maximum development. The following readings were taken from the farinograph: water absorption (%), arrival time(min), dough development time (min), dough stability(min) and farinograph quality number (FQN).

Extensograph test

The extensograph test was carried out of corn flour from the various blends of 10, 20 and 30% carrot and sweet potato powder according to the method described in the **A.A.C.C. (2000).** Using an Extensograph measure the following parameters: dough extensibility, dough resistance to extension (Elasticity), proportional number and dough energy.

Bakery Products

Formulation and preparation of corn flour crackers

Crackers were prepared by using the **Isik and Topkaya (2016)** method with a little modification. The control and the other formulations are presented in Table (1). In a mixing bowl, the dry and liquid ingredients were mixed for 3-4 minutes to form the dough, then left to rest for 10 minutes. The dough was rolled out as thin as possible -no thicker than 1/8 inch and cut out as square-shaped crackers. Crackers were baked in an electric oven at 200°C for 10 minutes. After baking, crackers were left in the oven for an additional 2 minutes with the heat off but with forced air circulation. This process simulated the drying and cooling stages of a commercial baking oven. Baked crackers were then removed from the oven and allowed to cool to room temperature. Crackers samples were stored in airtight containers before sensory evaluation.

Table (1): Formulation of Crackers

Ingredients (g)	Control	10% CP	20% CP	30% CP	10% PP	20% PP	30% PP
CF	450	405	360	315	405	360	315
CP	-	45	90	135	-	-	-
PP	-	-	-	-	45	90	135
Wheat starch	50	50	50	50	50	50	50
Water	300	300	315	320	300	300	315
Corn oil	75	75	75	75	75	75	75
Sugar	5	5	5	5	5	5	5
Salt	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Baking powder	5.0	5.0	5.0	5.0	5.0	5.0	5.0

CF,corn flour; CP, carrot powder; PP, sweet potato powder

Sensory Evaluation

Sensory evaluation was participated by invited ten staff panelists from the Home Economic Department, Faculty of Specific Education, Damietta University, Damietta, Egypt. Each panelist was asked to evaluate seven samples of crackers according to color, flavor, texture, taste, and overall acceptability. The evaluation was carried out according to the method of **(Abd El – latif, 1990)**

Statistical Analysis

The data obtained were statistically analyzed using a computer. The results were expressed as mean ± standard deviation (SD) and tested for significance using the one-way analysis of variance (ANOVA) test, according to Duncan’s multiple range test at ($P \leq 0.05$) probability. According to the method described by **Armitage & Berry (1987).**

RESULTS AND DISCUSSION

Chemical analyses of grains' flour and its composites with plant parts powder

Data in Table (2) showed the approximate chemical composition of control and composite RF samples. Partial replacement of RF with different percentages (10, 20 and 30%) of CP and PP led to an increase in crude fiber and ash and decrease in total protein and crude fat. At 30% substitution of CP, the rate of decreasing was recorded -15.34, -8.95 and -1.57% for the total protein, crude fat and total carbohydrates which was met at the same time with a rate of increase in moisture, crude fiber and ash by 3.79, 35.28 and 36.23%, respectively. Also, at 30% substitution of PP, the rate of decreasing was recorded -4.17, -19.82 and -18.90% for the moisture, total protein and crude fat which was met at the same time with a rate of increase in crude fiber, ash and total carbohydrates by 11.07, 34.05 and 1.83%, respectively. The rate of increasing or decreasing in the chemical composition parameters of the RF as the result of CP and PP substitution were exhibited a dose-dependent manner.

Table 2. Effect of mixing tested vegetables powder on the chemical composition of rice flour

Parameter (g/100g)	RF	RF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
Moisture	10.54 ±0.43 [a]	10.67 ±0.52 [a]	10.81 ±0.31 [a]	10.94 ±0.67 [a]	10.39 ±1.04 [a]	10.25 ±0.77 [a]	10.10 ±0.58 [a]
Total Protein	6.91 ±0.32 [a]	6.56 ±0.24 [a]	6.20 ±0.20 [a]	5.85 ±0.34 [b]	6.45 ±0.39 [a]	6.00 ±0.45 [ab]	5.54 ±0.37 [b]
Crude Fat	2.01±0.24 [a]	1.95 ±0.12 [a]	1.89 ±0.09 [a]	1.83 ±0.22 [a]	1.88 ±0.17 [a]	1.76 ±0.33 [ab]	1.63 ±0.09 [b]
Crude Fiber	2.89 ±0.19 [c]	3.40 ±0.21 [a]	3.92 ±0.51 [a]	4.43 ±0.75 [a]	3.00 ±0.36 [bc]	3.10 ±0.29 [b]	3.21 ±0.26 [ab]
Ash	1.38 ±0.11 [b]	1.55 ±0.13 [ab]	1.72 ±0.09 [a]	1.88 ±0.09 [a]	1.54 ±0.19 [b]	1.69 ±011 [a]	1.85 ±0.10 [a]
Carbohydrates	76.27 ±3.87 [a]	75.87 ±4.10 [a]	75.46 ±2.93 [ab]	75.07 ±3.05 [b]	76.74 ±2.90 [a]	77.02 ±2.18 [a]	77.67 ±1.89 [a]

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at $P \leq 0.05$.
RF, rice flour; CP, carrot powder; PP, sweet potato powder.

Table (3) showed the approximate chemical composition of the composite CF and control CF samples. The total protein and crude fat content lowered and the crude fiber, ash, and total carbohydrates enhanced when different proportions (10, 20 and 30%) of PP and CP were employed to partially replace CF. At 30% substitution of CP, the rates of decline for crude fat and total protein were -19.45% and -19.36, respectively. This was achieved at the same time that the rates of increase for moisture, total carbohydrates, ash, and crude fiber were 2.42, 0.49, 39.39, and 47.11 %, respectively. In addition, at 30% substitution of PP, the rate of reduction for moisture, crude fat and total protein were -5.19, -24.43 and -22.53 percent, respectively. These reductions were accompanied by increases in crude fiber, ash, and total carbohydrates of 8.01, 37.12, and 4.13%, respectively. It was shown that the CP and PP replacement had a dose-dependent effect on how quickly the CF's chemical composition parameters increased or decreased.

Table 3. Effect of mixing tested vegetables powder on the chemical composition of corn flour

Parameter (g/100g)	CF	CF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
Moisture	10.98 ±1.23 [a]	11.07 ±1.09 [a]	11.16 ±1.11 [a]	11.25 ±0.69 [a]	10.79 ±0.99 [a]	10.60 ±0.76 [a]	10.41 ±0.90 [a]
Total Protein	9.45 ±0.89 [a]	8.84 ±0.76 [a]	8.23 ±0.98 [ab]	7.62 ±0.58 [bc]	8.74 ±0.83 [a]	8.03 ±0.49 [b]	7.32 ±0.40 [c]
Crude Fat	4.01 ±1.03 [a]	3.75 ±0.30 [a]	3.49 ±0.52 [a]	3.23 ±0.44 [ab]	3.68 ±0.40 [a]	3.36 ±0.36 [a]	3.03±0.42 [b]
Crude Fiber	3.12 ±0.65 [b]	3.61 ±0.68 [a]	4.10 ±0.33 [a]	4.59 ±0.89 [a]	3.20 ±0.52 [b]	3.28 ±0.17 [ab]	3.37 ±0.56 [ab]
Ash	1.32 ±0.20 [b]	1.49 ±0.05 [ab]	1.67 ±0.10 [a]	1.84 ±0.34 [a]	1.48 ±0.19 [ab]	1.64 ±0.12 [a]	1.81 ±0.34 [a]
Carbohydrates	71.12 ±2.67 [b]	71.24 ±1.87 [b]	71.35 ±3.05 [b]	71.47 ±1.70 [b]	72.11 ±2.15 [ab]	73.09 ±2.59 [a]	74.06 ±2.76 [a]

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at $P \leq 0.05$.
CF, corn flour; CP, carrot powder; PP, sweet potato powder.

A composite the flour mixture (50%RF+50%CF) samples was shown in Table (4). When incorporated flours were partially substituted with varying percentages (10, 20 and 30%) of PP and CP, crude fiber and ash increased while total protein and crude fat declined. The rates of decrease at 30% substitution of CP were -17.72, -15.94, and -1.55% for total protein, crude fat, and carbs, respectively. These rates were met concurrently with increases in moisture, crude fiber and ash of 3.06, 49.83 and 37.77%, respectively. Additionally, with 30% replacement of PP, the moisture, crude fat and total protein reduced at a rate of -4.73, -22.59 and -21.39 %, respectively. This was balanced at the same time by an increase in crude fiber, ash, and total carbs of 9.30, 35.55, and 2.95%, respectively. As a result of substituting CP and PP, the combination flour's chemical composition parameters showed a dose-dependent rate of enhance or decline.

Table 4. Effect of mixing tested vegetables powder on the chemical composition of the flour mixture

Parameter (g/100g)	RF +CF	RF +CF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
Moisture	10.76 ±1.04 a	10.87 ±0.98 a	10.98 ± 0.98 a	11.09 ±0.88 a	10.59 ±1.06 a	10.42 ±1.08 a	10.25 ±1.11 a
Total Protein	8.18 ±0.89 a	7.70 ±0.59 b	7.22 ±0.94 c	6.73 ±0.47 d	7.60 ±0.45 b	7.01 ±0.48 c	6.43 ±0.55 e
Crude Fat	3.01 ±0.68 a	2.85 ±0.54b	2.69 ±0.55 b	2.53 ±0.30 bc	2.78 ±0.11 b	2.56 ±0.33 b	2.33 ±0.06 c
Crude Fiber	3.01 ±0.55 c	3.51 ±0.69 b	4.01 ±0.69 ab	4.51 ±0.28 a	3.10 ±0.25 c	3.19 ±0.20 b	3.29 ±0.33 b
Ash	1.35 ±0.03 d	1.51 ±0.44 c	1.69 ±0.52 b	1.86 ±0.27 a	1.51 ±0.20 c	1.67 ±0.31 b	1.83 ±0.11 a
Carbohydrates	73.69 ±2.79 a	73.56 ±3.04 a	73.41 ±1.78 a	73.28 ±2.05 a	74.42 ±3.12 a	75.15 ±2.06 a	75.87 ±1.06 a

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at $P \leq 0.05$.
CF, corn flour; RF, rice flour; CP, carrot powder; PP, sweet potato powder

In similar previous studies, **Caporizzi *et al*. (2023)** found that rice flour has a protein level of 7.3 g/100 g, a lipid content of 0.5 g/100 g, a moisture content of 12.91g/100 g, and a carbohydrate content of 87g/100 g. then, rice flour was low in fiber but high in carbohydrates, primarily starch, which is critical for its technological functionality during extrusion cooking.

For corn flour, **Adeloye *et al*. (2020)** found that it has a moisture content of 6.89%, an ash content of 1.76%, a crude protein content of 6.75%, a lipid content of 11.46%, a crude fiber content of 2.96%, and a nitrogen-free extract (NFE) content of 70.19%. In general, some previous studies agree with what was obtained in this study, while some other studies disagree with them. From all the above studies and others, it could be concluded that the chemical composition of grains flour including rice and corn vary with one or combination of the following factors, species, season, geographical location, light intensity and duration, conditions around, nutrients in soil, water salinity and residents' activities. Mixing rice and corn flours with the selected plant parts powder (carrot and sweet potato) leads to decrease in both protein and fat content but the opposite direction was recorded for crude fiber and ash content. Such observation could be attributed to the high ash and crude fiber content recorded in carrot and potato powders.

For example, **Garg *et al*. (2024)** found that carrot powder contain ash and fiber was 6.08 and 9.42%, respectively. For potato powder, **Roger *et al*. (2022) and Belkacemi (2022)** reported that sweet potato flour has an ash content of 1.3g/100 g and a fiber content of 3.87 g/100 g. Also, **Rabie *et al*. (2024)** found that sweet potato powder contained 2.94 and 3.26% for ash and crude fibers, respectively. Subsequently, the addition of carrot and potato powders to wheat flour samples leads to a highly significant increasing in their crude fiber and ash content. This property could be played many nutritional and therapeutic benefits, Fiber contributes to reduce the risk of developing various diseases including cardiovascular disease, diabetes, and constipation **(Elhassaneen *et al*., 2020; El-Hawary *et al*., 2023 and Elhassaneen *et al*., 2023)**.

Finally, Constipation is the most common gastrointestinal complaint in worldwide and consumption of fiber seems to relieve and prevent constipation. Data of the present study with the others confirmed that such tested plant parts could be used successfully in food technology and nutritional applications due to their sources for fiber and ash. In addition to these previous factors, they are gluten-free foodstuffs, which qualify them to play an important role in the nutrition of gluten-allergic patient, celiac disease.

Mineral of grains' flour and its composites with plant parts powder

Data in Table (5) showed the minerals content of control and composite RF samples. Partial replacement of RF with different percentages (10, 20 and 30%) of CP and PP led to an increase or decrease in its minerals content. At 30% substitution of CP, the rate of decreasing was recorded -6.42, -25.32, -9.93 and -23.04 % for the Mg, P, Fe and Zn which was met at the same time with a rate of increase in K, Na and Ca by 5.58, 34.11and 1.62 %, respectively. Also, at 30% substitution of PP, the rate of decreasing was recorded -22.26, -7.37 and -26.26 % for the P, Fe and Zn which was met at the same time with a rate of increase in K, Na, Ca and Mg by 23.14, 5.30, 47.75 and 22.67 %, respectively. The rate of increasing or decreasing in the chemical composition parameters of the RF as the result of CP and PP substitution were exhibited a dose-dependent manner.

Table 5. Effect of mixing tested vegetables powder on the minerals content of rice flour

Mineral (mg/100g)	RF	RF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
K	189.67±7.5 [b]	193.20±7.8 [b]	196.74±7.5 [b]	200.27±7.8 [ab]	204.30±8.9 [ab]	218.94±9.2 [a]	233.57±7.8 [a]
Na	41.65±2.3 [b]	46.39±3.3 [b]	51.12±3.2 [ab]	55.86±4.1 [a]	42.39±7.6 [a]	43.12±5.6 [a]	43.86±3.2 [a]
Ca	22.76±0.9b [b]	22.88±1.7 [b]	23.01±0.7 [b]	23.13±0.7 [b]	26.38±5.1 [ab]	30.01±1.9 [a]	33.63±2.2 [a]
Mg	21.65±0.6 [b]	21.19±1.3 [b]	20.72±1.2 [b]	20.26±0.6 [b]	23.29±3.4 [ab]	24.92±1.6 [a]	26.56±1.1 [a]
P	166.78±5.7 [a]	152.70±5.6 [b]	138.62±8.9 [c]	124.55±7.4 [d]	154.40±6.7 [b]	142.02±5.9[bc]	129.65±8.4 [d]
Fe	3.12±0.3 [a]	3.02±0.1 [a]	2.91±0.40 [a]	2.81±0.4 [a]	3.04±0.3 [a]	2.96±0.3 [a]	2.89±0.4 [a]
Zn	2.17±0.2 [a]	2.00±0.2 [a]	1.84±0.21 [ab]	1.67±0.2 [b]	1.98±0.3 [a]	1.79±0.2 [b]	1.60±0.1 [b]

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at $P \leq 0.05$. RF, rice flour; CP, carrot powder; PP, sweet potato powder.

Table (6) illustrates the mineral makeup of the control and composite CF samples. When CF was partially substituted with varied percentages (10, 20 and 30%) of CP and PP, the mineral makeup of the mixture changed. The rates of reduction for Mg, P, and Fe were -26.55, -17.81, and -6.13% when 30% of CP was substituted. This occurred at the same time that the rates of rise for K, Na, Ca, and Zn by77.14, 20.37, 7.89 and 10.81% respectively were satisfied. Moreover, at 30% PP replacement, the rates of decline for Na, Mg, P, Fe, and Zn were reported as -2.26, -22.29, -9.84, -3.06, and -8.10%. Concurrently, K and Ca grew at rates of 130.0 and 63.15%, respectively, and this was accomplished. It was shown that the rate at which the substitution of PP and CP altered the mineral content of the CF varied according to dose.

Table 6. Effect of mixing tested vegetables powder on the minerals content of corn flour

Mineral (mg/100g)	CF	CF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
K	63.00±2.9 [e]	79.20±5.6 [d]	95.40±67 [c]	111.6±9.7 [b]	90.30±6.8 [c]	117.6±8.9 [b]	144.9±9.8 [a]
Na	53.00±3.5 [b]	56.60±6.6 [ab]	60.20±1.9 [a]	63.8±6.5 [a]	52.60±5.7 [b]	52.2±4.5 [b]	51.8±4.5 [b]
Ca	19.00±1.9 [b]	19.50±2.5 [b]	20.00±0.3 [b]	20.5±2.3 [b]	23.00±1.3 [b]	27.0±2.3 [ab]	31.0±1.8 [a]
Mg	148.00±4.6 [a]	134.9±9 [b]	121.80±8.9 [c]	108.7±5.8[d]	137.0±7.8 [b]	126.0±7.8 [bc]	115.0±8.5 [cd]
P	64.00±5.4 [a]	60.20±3.7 [a]	56.40±3.4 [b]	52.6±3.4 [b]	61.90±4.5 [a]	59.80±4.5 [ab]	57.7±5.7 [b]
Fe	2.61±0.7 [a]	2.56±0.3 [a]	2.51±0.2 [b]	2.45±0.8 [c]	2.58±0.7 [a]	2.56±0.2 [a]	2.53±0.1 [ab]
Zn	0.37±0.1 [a]	0.38±0.1 [a]	0.40±0.1 [a]	0.41±0.1 [a]	0.36±0.1 [a]	0.35±0.1 [a]	0.34±0.03 [a]

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at $P \leq 0.05$. CF, corn flour; CP, carrot powder; PP, sweet potato powder.

Table (7) presents the mineral content of the control and composite combined the flour mixture (50%RF+ 50%CF) samples. The data indicated that. The mineral content of the flour combination increased or decreased when it was partially replaced with varying percentages (10, 20 and 30%) of CP and PP. At 30% substitution of CP, the rate of reduction was recorded as -23.98, -23.24, -8.36, and -18.11% for Mg, P, Fe, and Zn, which was met at the same time with a rate of rise in K, Na, and Ca of 23.42, 26.41, and 4.50%, respectively. Additionally at 30% replacement of PP, the rate of decrease was recorded as -16.56, -18.82, -5.57, and -23.62% for Mg, P, Fe, and Zn, which was met at the same time through a rate of increase in K, Na, and Ca of 49.77, 1.05, and 54.78%, respectively. The rate of increase or decrease in the combination sample's mineral content as a result of CP and PP replacement was dose-dependent.

Table 7. Effect of mixing tested vegetables powder on the minerals content of the flour mixture

Mineral (mg/100g)	RF +CF	RF +CF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
K	126.34±2.7 [e]	136.20±4.9 [d]	146.07±7.6 [cd]	155.93±5.7 [c]	147.30±6.9 [cd]	168.27±3.7 [b]	189.23±8.4 [a]
Na	47.33±2.0 [b]	51.49±5.6 [b]	55.66±3.5 [ab]	59.83±2.3 [a]	47.49±4.6 [b]	47.66±2.1 [b]	47.83±5.7 [b]
Ca	20.88±0.9 [b]	21.19±0.9 [b]	21.50±0.9 [b]	21.82±0.9 [b]	24.69±2.3 [b]	28.50±0.99 [ab]	32.32±3.4 [a]
Mg	84.83±1.1 [a]	78.04±3.5 [b]	71.26±6.3 [c]	64.48±3.6 [d]	80.14±6.7 [ab]	75.46±4.5 [b]	70.78±1.9 [c]
P	115.39±3.6 [a]	106.45±4.6 [ab]	97.51±4.5 [b]	88.57±5.7 [c]	108.15±9.4 [a]	100.91±6.8 [b]	93.67±5.8 [bc]
Fe	2.87±0.4 [a]	2.79±0.2 [a]	2.71±0.7 [a]	2.63±0.2 [b]	2.81±0.7 [a]	2.76±0.4 [a]	2.71±0.5 [ab]
Zn	1.27±0.2 [a]	1.19±0. 1 [a]	1.12±0.3 [ab]	1.04±0.2 [b]	1.17±0.3 [a]	1.07±0.2 [b]	0.97±0.3 [c]

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at $P \leq 0.05$. CF, corn flour; RF, rice flour; CP, carrot powder; PP, sweet potato powder.

The results of the current study are partly consistent with many similar studies conducted previously. For example**, Hassan *et al.* (2020)** reported that rice flour contains a higher amount of minerals like Ca, P, K, Mg, Na, Fe, Zn, Cu, and Mn which are 72.85 mg, 229.57mg, 133.69mg, 36.87mg, 72.42 mg, 5.34 mg, 2.9 mg, 0.89mg, 20.35 mg respectively per 100g flour. Also, the concentration of phosphorus was higher in yellow corn flour (208.50 mg/100g), followed by calcium, potassium, magnesium and sodium being127.92, 118.65, 113.94 and 63.14 mg/100g, respectively. Trace minerals were 3.75, 1.18 and 0.89 mg/100g for manganese, iron and zinc, respectively **(Rabie *et al.*, 2024)**. For the composite samples, wheat and carrot flour were used to produce cookies in the following blend ratios: 100:0:0, 90:10:0, 90:0:10, 80:15:5, 70:20:10. An increase in the mineral: calcium, potassium, and sodium composition of cookie samples except for zinc which decreased from 7.12 to 5.75mg/100g. The increase in calcium and other minerals can be attributed to the high mineral content of carrot **(Guyih *et al.*, 2020)**.

On the other side, potassium was the highest major minerals in sweet potato powder (582.39 mg/100g), the rest of elements were 198.22, 142.96, 132.70, 123.58, 2.87, 2.15 and 0.46 mg/100g for phosphorus, sodium, calcium, magnesium, manganese, iron and zinc in sweet potato **(Rabie *et al*., 2024).** In general, potassium intake alone or as part of an entire diet pattern may reduce blood pressure, thereby decreasing the risk of developing cardiovascular disease. **(Katsuya *et al*., 2024).** Also, potassium intake has conclusively reduced urinary calcium excretion, thus creating a positive calcium balance. In the longer term, this is likely to have very beneficial effects on skeletal health and the concomitant risk of osteoporosis. **(Xu *et al*., 2024)**. Sodium is the main cation of the extracellular fluid and plays a major role in the regulation of the extracellular volume and water balance. The importance of sodium is also noticeable **(Tremblay *et al*., 2024).** dietary calcium has a beneficial effect on cardiovascular risk, cholesterol-lowering effect and interaction with fatty acids and bile acids **(Qiu *et al*., 2024).**

Effect of mixing tested vegetables powder on the rheological properties of corn flour

Farinograph parameters

Data in Table (8) and figure (1) showed the effect of mixing tested vegetables powders on the farinograph parameters of the corn flour (CF). Partial replacement of CF with different percentages (10, 20 and 30%) of carrot powder (CP) and sweet potato powders (PP) led to an decrease or decrease in its farinograph parameters content. At 30% substitution of CP, the rate of decreasing was recorded -10.00, -10.31, -9.65, -9.87% for the water absorption, arrival time, dough development time, dough stability and farinograph quality number, respectively. Also, at 30% substitution of PP, the rate of decreasing was recorded -21.57, -22.22, -21.23, -21.55 and -21.56% for the water absorption, arrival time, dough development time, dough stability and farinograph quality number, respectively. the rate of increasing or decreasing in the farinograph parameters of the CF as the result of CP and PP substitution were exhibited a dose-dependent manner.

Table 8. Effect of mixing tested vegetables powder on the farinograph parameters of corn flour

Parameter	CF	CF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
Water absorption (%)	41.40±0.98 ^{a}	39.82±1.11 ^{a}	38.81±1.23 ^{a}	37.26±2.10 ^{ab}	35.65±2.11 ^{b}	35.19±2.87 ^{b}	32.47±1.67 ^{b}
Arrival time (min)	1.26±0.08 ^{a}	1.21±0.06 ^{a}	1.18±0.20 ^{a}	1.13±0.32 ^{a}	1.08±0.20 ^{ab}	1.07±0.09 ^{ab}	0.98±0.09 $^{a b}$
Dough development time (min)	2.59±0.07 ^{a}	2.50±0.10 ^{a}	2.43±0.09 ^{a}	2.34±0.09 ^{ab}	2.23±0.11 ^{b}	2.21±0.11 ^{b}	2.04±0.05 ^{c}
Dough stability (min)	3.85±0.11^{a}	3.70±0.10 ^{a}	3.61±0.43 ^{a}	3.47±0.13 ^{ab}	3.32±0.23 ^{b}	3.27±0.04 ^{b}	3.02±0.32 ^{c}
Farinograph quality number (FQN)	115.20±3.22 a	110.82±4.11 a	107.99±1.78 ab	103.69±2.65 ^{b}	99.20±3.09 ^{bc}	97.91±3.05^{a}	90.36±4.10 ^{c}

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at $P \leq 0.05$.
CF, corn flour; CP, carrot powder; PP, sweet potato powder.

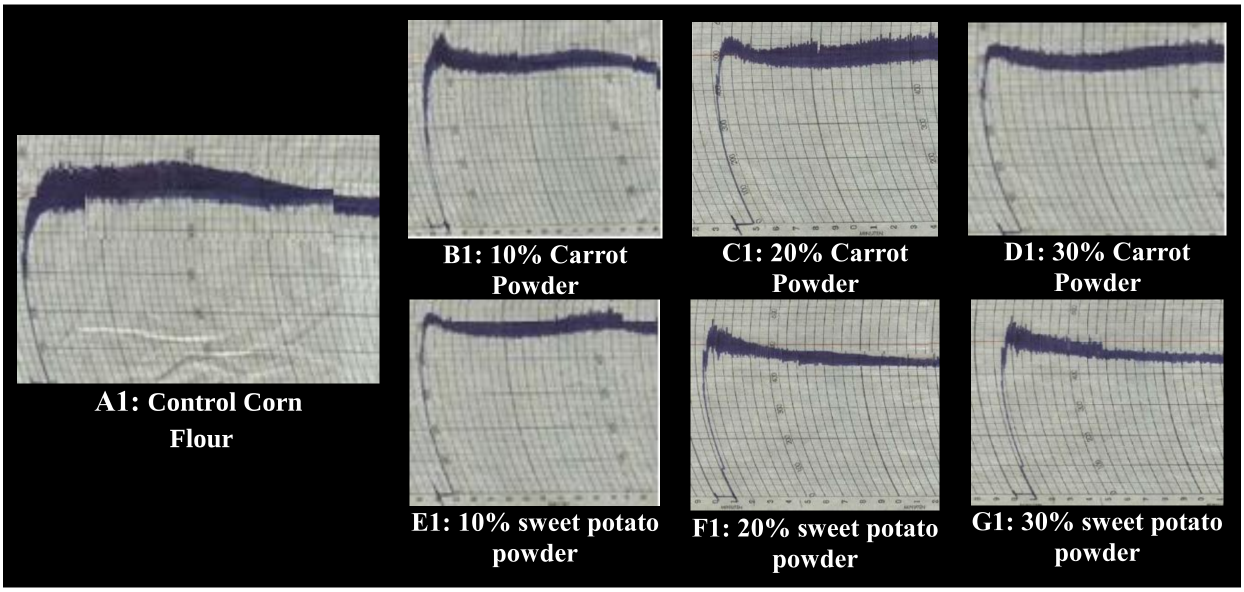

Fig1. Effect of mixing tested vegetables powder on the farinograph parameters of corn flour

Results of the present study showed that all farinograph parameters were determined for rice and corn flour samples substituted with 10 to 30% of carrot and sweet potato powder and their mixture. The incorporating of plant parts in flour samples decreased the dough water absorption. This decrement may be due to high content of protein content in plant parts. Such data are not in accordance with that reported by **Mashal, (2016).** Also, **Ashoush & Gadallah, (2011)** reported that farinograph data of wheat flour incorporated with mango peel powder (with high fiber content) showed an increase in water absorption.

The dough development time decreased and dough stability with incorporation of plant parts. This may be due to low content of protein in all of the tested plant parts. Our data are not in agreement with that mentioned by **Sayed (2016) and Mashal (2016)**. Such as mentioned by **Mehram (2019)** and **Rahman, *et al*. (2023)** the peak dough development time was affected and varied proportionally with the protein content of the flour and its quality. Consequently, the affecting on the peak dough development of samples flour as the result of plant parts addition can comes through changes occurred in wheat flour protein quality. Also, dough stability is the most important index for dough strength. Addition of plant parts (carrot and sweet potato powders and their mixture) to flour samples showed markedly smaller stability periods than the control samples. This affect could be attributed to the effect of plant parts addition on the quality of protein in particular the binding force property **(Sayed, 2016 and Mashal, 2016).**

Extensograph parameters

Data in Table (9) and Figure (2) showed the effect of mixing tested vegetables powders on the extensograph parameters of the CF. Partial replacement of CF with different percentages (10, 20 and 30%) of CP and sweet PP led to an increase or decrease in its extensograph parameters content. At 30% substitution of CP, the rate of decreasing was recorded -9.98, -9.98, -9.88 and -9.98% for extensibility, relative resistance to extension, proportional number and energy, respectively. Also, at 30% substitution of PP, the rate of decreasing was recorded -21.56, -21.56, -21.51 and -21.56% for extensibility, relative resistance to extension, proportional number and energy, respectively.

Table 9. Effect of mixing tested vegetables powder on the extensograph parameters of corn flour

Parameter	CF	CF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
Extensibility (mm)	112.35±3.2 a	108.08±4.1 a	105.32±3.7 a	101.13±2.9 ab	96.75±1.9 b	95.49±2.7 b	88.12±2.9 c
Relative resistance to extension (BU)	344.71±5.7 a	331.61±6.5 b	323.16±8.9 b	310.30±4.6 c	296.86±3.6 d	293.00±5.8 d	270.38±3.7 e
Proportional number	1.72±0.21 a	1.66±0.11 a	1.62±0.23 a	1.55±0.12 ab	1.48±0.20 b	1.47±0.23 b	1.35±0.21 b
Energy (cm^2)	70.48±2.56 a	67.80±2.6 a	66.07±4.1 a	63.44±3.9 ab	60.69±5.9 b	59.91±4.6 b	55.28±0.89 b

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at *P* ≤0.05. CF, corn flour; CP, carrot powder; PP, sweet potato powder.

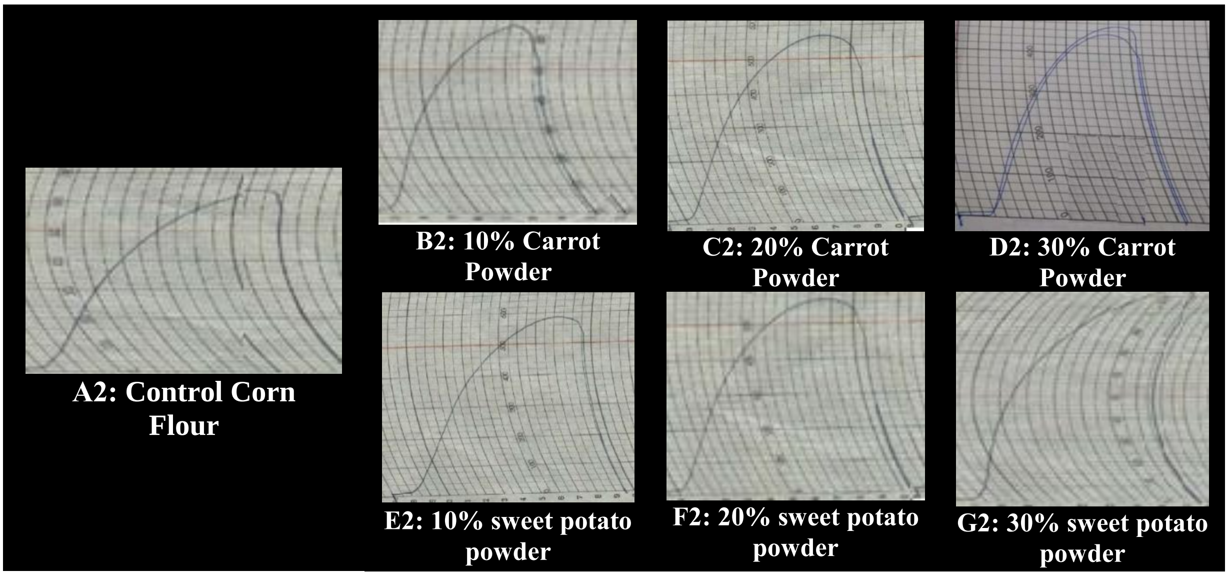

Fig 2. Effect of mixing tested vegetables powder on the extensograph parameters of corn flour

Data of the present study show the extensograph results of corn flour control dough and dough's with additions of plant parts (carrot and sweet potato powders). Dough strength (Extensibility) determined by the area under the curve and is proportional to energy needed to bring about rupture. The incorporating of plant parts (carrot and sweet potato powders) in dough decreased the extensibility for corn flour (control samples). Dough resistance to extension in BU is the most important index for dough ability to retain gas.

Addition of plant parts (carrot and sweet potato powders) to corn flour showed markedly decreasing resistance to extension than the corn flour (control sample). The effect of plant parts (carrot and sweet potato powders) on decreasing the extensibility of the corn flour may be due to the alteration of the viscosity **(Hussein *et al*., 2024).** Also, such data of the present study are not accordance with that observed by several authors **(Mohammed, 2013; Sayed, 2016).**

Sensory evaluation

<u>Sensory evaluation score of substitution with vegetables powder on crackers of corn flour</u>

Data in Table (10) showed the sensory evaluation score of substitution with vegetables powder on the crackers of corn flour (CF). Partial replacement of CF with different percentages (10-30%) of carrot powder (CP) and sweet potato powders (PP) led to a decrease or decrease in its sensory evaluation scores. At 30% substitution of CP, the rate of decreasing was recorded -6.05, -8.8, -15.20, -15.30, -7.55 and -10.57 % for the color, odor, texture, taste, overall acceptability, and total score, respectively. Also, at 30% substitution of PP, the rate of decreasing was recorded -2.8, -2.4, -8.2, -6.11, -3.55 and -4.60% for the color, odor, texture, taste, overall acceptability, and total score, respectively. the rate of increasing or decreasing in the bioactive compounds content of the CF as the result of CP and PP substitution were exhibited a dose-dependent manner.

Table 10. sensory evaluation score of substitution with vegetables powder on crackers of corn flour

Sensory characteristics	CF	CF composites					
		CP (10%)	CP (20%)	CP (30%)	PP (10%)	PP (20%)	PP (30%)
Color (20)	20.00 ± 0.00^{a}	19.37 ± 0.93^{ab}	18.80 ± 1.54^{b}	18.79± 1.31^{b}	19.89 ± 0.31^{a}	19.56 ± 0.70^{ab}	19.44 ± 0.71^{ab}
Odor (20)	20.00 ± 0.00^{a}	19.07± 1.25^{bcd}	18.71 ± 1.24^{cd}	18.24 ±1.69^{d}	19.69 ± 0.47^{ab}	19.72 ± 0.53^{ab}	19.52 ±0.71^{abc}
Texture (20)	20.00 ± 0.00^{a}	17.67 ± 1.73^{bc}	17.11 ± 1.48^{c}	16.96± 1.31^{c}	18.61 ± 0.73^{b}	18.25 ± 1.36^{b}	18.36 ± 0.64^{b}
Taste (20)	19.80 ± 0.63^{a}	18.32 ± 0.57^{b}	17.26 ± 1.24^{c}	16.77± 1.08^{c}	19.00 ± 0.66^{b}	18.98 ± 0.78^{b}	18.59 ± 0.41^{b}
Overall acceptability (20)	20.00 ± 0.00^{a}	19.13 ± 1.17^{abc}	18.67 ± 1.57^{bc}	18.49± 1.76^{c}	19.70 ± 0.48^{ab}	19.33± 1.24^{abc}	19.29±0.81^{abc}
Total score (100)	99.80 ± 0.63^{a}	93.56 ± 3.78^{cd}	90.55 ± 4.82^{de}	89.25 ± 5.38^{e}	96.80 ± 2.20^{ab}	96.20 ± 3.05^{bc}	95.20 ± 2.34^{bc}

Each value represents the mean ± SD (n= 3). Means with different superscript letters are different significantly at *P* ≤0.05. CF, corn flour; cp, carrot powder; pp, sweet potato powder.

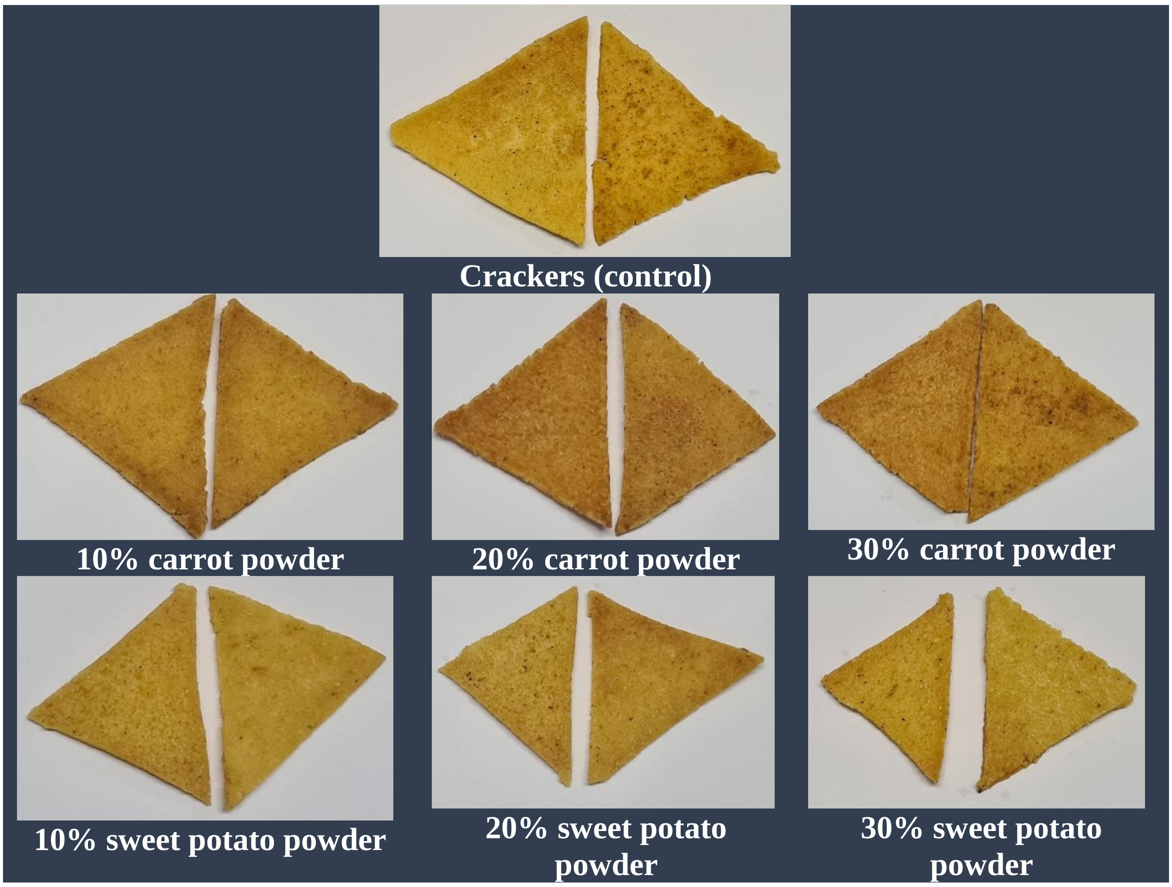

Photo1: Crackers with different levels of carrot and sweet potato powder

Generally, the results of the sensory evaluation demonstrated that crackers produced from corn flour and supplemented with (10, 20 and 30%) of carrot powder, and sweet potato powder were acceptable.

The present data are in accordance with that obtained by **Mashal, (2016)** investigated the effect of different agricultural processing by-products (potato, onion and prickly pear peels powder) at different replacing levels ranging 5-10 % on sensory properties of breads and biscuits and found that over all acceptable breads and biscuits with were obtained by incorporating up to 5%. In similar study, **Arepally *et al*. (2020) and Yang *et al*. (2021)** reported that the initial acceptance of baked products is much influenced by colour, which can also be an indicator of baking completion. The desirable colour of backed products is mainly due to the Millard browning during baking. However, in carrot and sweet potato powders blended to different products, the colour could be partially contributed by the phenolics and carotenoids in such plant products which imparts a yellowish/brownish colour to the bakery products. Similar data were reported by **Brannan *et al*., (2001)** who observed that an increased flour and thus muffin visual lightness (with more yellowness and brownness rather than dark and yellow green) yield a higher aroma, texture and colour acceptability scores. Data of the sensory evaluation with the chemical, physical and rheological properties of the bakery products incorporated with the tested plant parts recommended the using of such product as an important functional food and could be potentially applied many therapeutic nutrition applications such as celiac patients.

In conclusion, the present study has demonstrated the potency of mixing various plant parts (carrot and sweet potato powders) with rice flour, corn flour, and their mixture, which improved the chemical composition and mineral content. Furthermore, the mixing of the same plant parts with corn flour improved the rheological properties and sensory evaluation of the free-gluten bakery products for the prevention and treatment of celiac or gluten-sensitivity and its complications.

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التأثيرات المحتملة لخلط أجزاء نباتية على الخواص الكيميائية والريولوجية والحسية للمنتجات الخالية من الجلوتين

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الملخص

تهدف الدراسة الحالية إلى دراسة التأثير المحتمل لخلط أجزاء نباتية، مساحيق الجزر (CP) والبطاطا الحلوة (PP) على التركيب الكيميائي ومحتوى المعادن والخصائص الريولوجية والتقييم الحسي لمنتجات المخابز الخالية من الجلوتين والتي تناسب مرضي الاضطرابات الهضمية وحساسية الجلوتين.

ولهذا الغرض تم إضافة ثلاث مستويات مختلفة ١٠ ،٢٠ ،٣٠% من أجزاء النبات (CP وPP) كبديل لدقيق الأرز (RF)، ودقيق الذرة (CF)، وخليط الدقيق (٥٠%أرز+٥٠%ذرة). وقد أظهرت نتائج دراسة التركيب الكيميائي ان استبدال دقيق الأرز ودقيق الذرة ومخلوطهما بنسب (١٠%، ٢٠% ،٣٠%) بمسحوق الجزر أدي الي زيادة محتوي الرطوبة بمعدل ٣,٧٩%، ٢,٤٢% ،٣,٠٦%، الالياف الخام ٣٥,٢٨% ،٤٧,١١%، ٤٩,٨٣% والرماد ٣٦,٢٣% ،٣٩,٣٩% و٣٧,٧٧%، وانخفاض محتوي البروتين الكلي بمعدل -١٥,٣٤%، -١٩,٣٦%، -١٧,٧٢%، الدهون الخام -٨,٩٥%، -١٩,٤٥%، -١٥,٩٤%. في حين ان استبدال دقيق الأرز والذرة ومخلوطهما بنسب مختلفة (١٠%، ٢٠% ،٣٠%) من مسحوق البطاطا الحلوى، أدي الي زيادة في محتوي الالياف الخام بمعدل ١١,٠٧%، ٨,٠١%، ٩,٣٠%، الرماد ٣٤,٠٥%، ٣٧,١٢%، ٣٥,٥٥%، والكربوهيدرات ١,٨٣%، ٤,١٣%، ٢,٩٥%، وانخفاض في محتوي الرطوبة بمعدل -٤,١٧%، -٥,١٩%، -٤,٧٣، البروتين الكلي -١٩,٨٢%، -٢٢,٥٣%، -٢١,٣٩%، والدهون الخام -١٨,٩٠%، -٢٤,٤٣%، -٢٢,٥٩%. وبالنسبة للمحتوي المعدني، أدى استبدال نفس النسب من مسحوق الجزر الي زيادة محتوي البوتاسيوم بمعدل ٥,٥٨%، ٧٧,١٤%، ٢٣,٤٢% والصوديوم ٣٤,١١%، ٢٠,٣٧%، ٢٦,٤١%، والكالسيوم ١,٦٢%، ٧,٨٩% ،٤,٥٠%، وفي ذات الوقت وجد انخفاض في محتوي الفوسفور بمعدل -٢٥,٣٢%، -١٧,٨١%، -٢٣,٢٤% والحديد -٩,٩٣%، -٦,١٣%، -٨,٣٦% مقارنة بالعينات الضابطة (دقيق الأرز والذرة ومخلوطهما). أدي استبدال دقيق الأرز والذرة ومخلوطهما بذات النسب من مسحوق البطاطا الحلوة الي زيادة محتوي البوتاسيوم بمعدل ٢٣,١٤%، ١٣٠%، ٤٩,٧٧%، الكالسيوم ٤٧,٧٥%، ٦٣,١٥%،٥٤,٧٨%، في حين انخفض محتوي الفوسفور بمعدل -٢٢,٢٦%، -٩,٨٤%، -١٨,٨٢%، والحديد -٧,٣٧%، -٣,٠٦%، -٥,٥٧% والزنك -٢٦,٢٦%، -٨,١٠%، -٢٣,٦٢%. كما أظهرت نتائج الخواص الريولوجية للعجين دقيق الذرة (الفارينوجراف والإكستنسوجراف) أن إضافة مسحوق الجزر والبطاطا الحلوة بالنسب (١٠%،٢٠%،٣٠%) أدي الي انخفاض في امتصاص الماء، وقت الوصول، وقت إنضاج العجين، ثبات العجين، ورقم جودة الفارينوجراف، قوة الشد أو المطاطية، مقاومة العجين للمطاطية، الرقم النسبي وطاقة التخمر مقارنة بالعينة الضابطة (١٠٠%دقيق الذرة). هذا وأظهرت نتائج التقييم الحسي قبول المقرمشات المنتجة من دقيق الذرة بنسب استبدال ١٠%،٢٠%،٣٠% كل من مسحوق الجزر والبطاطا الحلوة. وقد خلصت الدراسة الحالية الي إمكانية إضافة أجزاء نباتية من مسحوق الجزر أو البطاطا الحلوة لتصنيع منتجات خالية من الجلوتين لتقليل مخاطر مرض الاضطرابات الهضمية وحساسية الجلوتين.

الكلمات المفتاحية: مسحوق الجزر ،مسحوق البطاطا الحلوة، دقيق الأرز ،دقيق الذرة ،محتوى المعادن، مرض الاضطرابات الهضمية.