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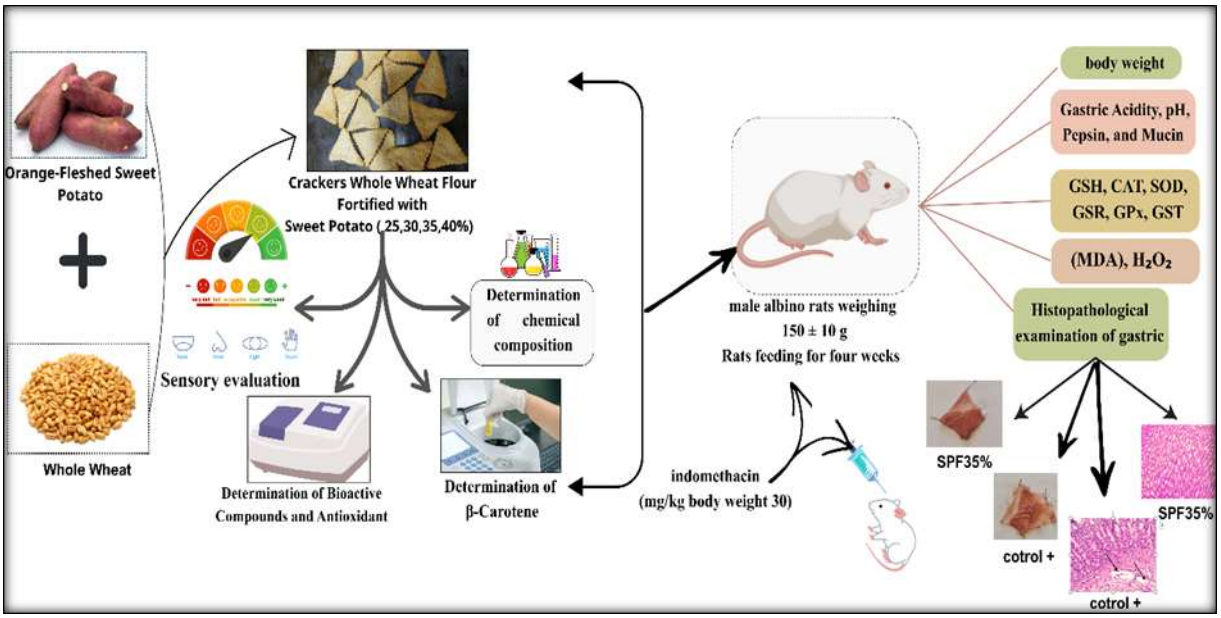
Abstract:

Orange-fleshed sweet potato (OFSP) is abundant in β-carotene and antioxidants, exhibiting significant gastroprotective properties. This study evaluated the impact of partially substituting whole wheat flour with OFSP flour in crackers on their nutritional, phytochemical, and sensory characteristics, as well as their therapeutic potential against indomethacin-induced gastric ulcers in rats. In the biological study, thirty male albino rats (150 ± 10 g) were randomly assigned into five groups (n = 6). Group 1 (C−), the negative control, received a standard diet plus 25g of whole wheat crackers. Gastric ulcers were induced in the remaining groups (2-5) by oral indomethacin (30 mg/kg). Group 2 (C+ positive control) received a standard diet plus 25 g whole wheat crackers, while Groups 3, 4, and 5 were supplemented with OFSP-fortified crackers at (25%, 30%, and 35%) substitution levels, respectively. The feeding trial lasted for four weeks. The results showed that at 40% OFSP substitution, protein and fat declined to 6.80% and 6.12%, while ash, fiber, carbohydrates, and β-carotene increased to 3.30%, 16.92%, 68.99%, and 15.67 µg/100 g, respectively. Phenolics, flavonoids, ascorbic acid, and DPPH inhibition rose to 56.2, 34.71, 8.91, and 65.0% versus 5.61, 3.50, 0.40, and 16.21 in the control ($p < 0.001$). Sensory attributes showed no differences up to 35%, but 40% caused significant declines ($p \leq 0.05$). In ulcerated rats, gastric pH increased from 1.61 (control, C+) to 3.10 (SPC 35%), and mucin doubled (0.37 → 0.76 g/mL), while acidity and pepsin decreased (104.69 → 55.20 mEq/L; 3.24 → 1.91 g/mL). Antioxidant enzymes (CAT, SOD, GSH, GST) improved from 1.30, 233, 163, 175 (C+) to 5.65, 580, 318, 286 (SPC 35%). Oxidative stress markers (MDA, H_2O_2) declined from 9.75 and 1.47 (C+) to 3.0 and 0.50, approaching normal values (1.40 and 0.08 in C−). The gastric mucosa of C+ rats displayed necrosis, oedema, and inflammatory infiltration, while therapy with SPC 35% maintained nearly normal architecture with just mild superficial lesions. OFSP-supplemented crackers improved nutritional and antioxidant values while offering gastroprotective benefits for gastric health.

Keywords: Crackers, Orange-fleshed sweet potato, Fortification, Gastric ulcers, Sensory evaluation, Antioxidantactivity, Therapeuticeffect

Graphical Abstract



الملخص العربي

الخصائص الحسية والتأثير العلاجي لكراكرز دقيق القمح الكامل المدعم بدقيق البطاطا الحلوة البرتقالية على قرحة المعدة التي تم إحداثها تجريبياً لدى الفئران

تُعَدّ البطاطا الحلوة البرتقالية اللون (OFSP) مصدرًا غنيًا بالبيتا–كاروتين ومضادات الأكسدة، حيث تمتاز بخصائص وقائية للمعدة. هدفت هذه الدراسة إلى تقييم الخصائص الكيميائية والحسية للكراكرز المحضر من القمح الكامل المدعم بدقيق البطاطا الحلوة البرتقالية بنسب مختلفة ودورة العلاجي ضد قرحة المعدة المستحثة بالاندوميثاسين في الجرذان. تم تقسيم عدد (٣٠) من ذكور الجرذان البيضاء (١٥٠ ± ١٠ جم) عشوائيًا إلى خمس مجموعات كل منها تحتوي على ٦ جرذان المجموعة الأولى الضابطة السالبة : تلقت الغذاء القياسي مضافًا إليه ٢٥ جم من كراكرز القمح الكامل. أما المجموعات (٢–٥) فقد استُحثت لديها قرحة المعدة عن طريق الإعطاء الفموي للاندوميثاسين (٣٠ ملجم/كجم). المجموعة الثانية الضابطة الموجبة تلقت غذاءً قياسيًا مع ٢٥ جم من كراكرز القمح الكامل، في حين تلقت المجموعات الثالثة والرابعة والخامسة كراكرز مدعّم بالبطاطا الحلوة البرتقالية بنسبة مختلفة (٢٥%، ٣٠%، ٣٥%) على التوالي. استمرت فترة التغذية لمدة ٤ أسابيع.أظهرت النتائج أنّ نسبة التدعيم بـ ٤٠% من دقيق القمح بدقيق البطاطا الحلوة أدى إلى انخفاض محتوى البروتين والدهن إلى ٦.٨٠% و٦.١٢%، بينما ارتفع محتوى الرماد والألياف والكربوهيدرات والبيتا–كاروتين إلى ٣.٣٠%، ١٦.٩٢%، ٦٨.٩٩%، و١٥.٦٧ ميكروجرام/١٠٠ جم، على التوالي. كما ازدادت المركبات الفينولية والفلافونويدات وحمض الأسكوربيك والنشاط المضاد للجذور الحرة (DPPH) بصورة معنوية مقارنة بالضابطة الموجبة ($p < 0.001$) . ولم تظهر معايير التقييم الحسي فروق معنوية حتى مستوى ٣٥%، بينما تسبب نسبة ٤٠% في انخفاض ملحوظ في تلك المعايير. ارتفع الأس الهيدروجيني للمعدة من ١.٦١ في مجموعة الضابطة الموجبة إلى ٣.١٠ في مجموعة(SPC 35%) ، وتضاعف محتوى الميوسين (٠.٣٧ الى ٠.٧٦ جم/مل)، في حين انخفضت الحموضة

الكلية والنشاط البيبسين (١٠٤.٦٩ الى ٥٥.٢٠ ملي مكافئ/لتر؛ ٣.٢٤ الى ١.٩١ جم/مل) على التوالي. كما تحسنت مستويات الإنزيمات المضادة للأكسدة (CAT, SOD, GSH, GST) بشكل ملحوظ، بينما انخفضت مؤشرات الإجهاد التأكسدي (MDA, H_2O_2) إلى مستويات قريبة من الطبيعية. وقد أظهرت الفحوص النسيجية حدوث ثقوب والتهاب في الغشاء المخاطي للمعدة في المجموعة ضابطة الموجبة ، في حين اظهر العلاج بكراكرز SPC 35% تحسن في البنية النسيجية تقترب من الانسجة الطبيعية مع وجود خدوش سطحية طفيفة. هذه النتائج بينت أن كراكرز البطاطا الحلوة البرتقالية بنسبة ٣٥% حسّن من القيمة الغذائية ، مضادات الأكسدة و فوائد علاجية للمعدة المصابة بالقرحة مما يدعم إمكانية استخدامها كغذاء وظيفي اقتصادي لتعزيز صحة المعدة.

introduction

Food fortification, as defined by the World Health Organization (WHO), is the deliberate incorporation of one or more micronutrients into food items to enhance their nutritional value, avert specific deficiencies, and provide health advantages **(Kruger *et al.*, 2020; Poniedziałek *et al.*, 2020)**. Fortification involves enhancing regularly consumed foods, such as cereals, to serve as a public health approach designed to increase the intake of essential elements **(Singh *et al.*, 2016; Ashraf, 2025)**. Food-to-food fortification entails the integration of micronutrient-rich foods into recipes and, crucially, into commercial food formulations to enhance their micronutrient content **(Mihai *et al.*, 2025)**.

Sweet potato (*Ipomea batatas* L.) is a vegetable crop in many countries, including Egypt. It belongs to the Convolvulaceae family, which encompasses approximately 400 Ipomea species found. The potato is the sole crop of economic significance**(Mwanga *et al.*, 2017)**. Sweet potato is one of the two significant crops, with common beans, that greatly contribute to the traditional cuisines of many countries. Orange-fleshed sweet potato, is one of the innovative crop that provides a source of beta-carotene and essential nutrients, potentially improving the nutritional status of the consumers **(Atobrah, 2020)**. Also, it is considered a valuable functional food due to its high content of vitamins, dietary fiber, minerals, and polyphenolic compounds **(Neela and Fanta, 2019)**. β-carotene in OFSP is a precursor of vitamin A, which plays a critical role in immunity, vision, and antioxidant protection. Additionally, carotenoid and phenolic extracts of (OFSP) exhibit an important antioxidant and gastroprotective properties against substances that induce gastric issues **(Abewoy *et al.*, 2024)**.

Crackers are considered one of the most widely consumed bakery products due to their long shelf-life, and consumer acceptability. In recent years, extensive attention has been given to the crackers fortification with functional components to improve the nutritional profile and enhance the health benefits **(Gebreselassie and Clifford, 2016)**. Sweet potato, mainly the orange-fleshed has been combined into bakery products due to its richness in β-carotene, bioactive compounds, dietary fiber, and antioxidants **(Rosell *et al.*, 2024)**. Numerous studies have confirmed that crackers of sweet potato exhibit improved nutritional value and sensory properties compared to wheat-based crackers **(Nailwal, 2013)**.

Moreover, previous studies focused on the compositional, physicochemical and sensory properties of sweet potato crackers due to their therapeutic applications. Until

now, no more investigation evaluated the role of sweet potato crackers as functional foods for the management of gastric ulcer **(Rosell *et al.*, 2024)**. This indicates a research deficit due to the rising global incidence of stomach ulcers and the increasing interest in dietary approaches for their prevention and management. Non-steroidal anti-inflammatory drugs (NSAIDs) such as indomethacin, and diclofenac are frequently prescribed for their anti-inflammatory effects however, extended use is associated with gastrointestinal complications, including erosion and perforation of gastric ulcers **(Mlodawska *et al.*, 2022)**.

Stomach ulcers are mucosal lesions that extend through the muscularis mucosae, typically surpassing 5 mm in diameter, and arise from a disruption in the equilibrium between protective and harmful stomach elements **(Khan *et al.*, 2023)**.

Risk factors like alcohol intake, excessive HCl secretion, oxidative stress, and NSAID usage intensify stomach damage and ulcer development **(Khan *et al.*, 2023)**. The anti-ulcer medications are the usual treatment; however, they are linked to negative side effects including nausea, pneumonia, diarrhoea and depression **(Savarino *et al.*, 2016)**. These disadvantages underscore the necessity of investigating natural food based options that could mitigate stomach ulcers with reduced complications. Therefore, the current study was designed to investigate the **sensory properties and therapeutic impact of orange-fleshed sweet potato-fortified crackers** on rats with indomethacin-induced gastric ulcers, aiming to provide a natural and functional alternative for gastric ulcer management.

Materials and Methods

Materials

Sweet potato variety (orange), whole wheat flour, sugar, vanilla, butter, eggs, salt, baking powder, and powdered milk were obtained from Fathalla Market in Alexandria, Egypt.

Animals: Thirty male albino rats of the Sprague-Dawley strain, weighing 150 ± 10 g, were obtained from the Institute of Graduate Studies and Research, Alexandria University, Egypt. The animals were acclimatized for two weeks. Rats were housed in plastic cages under controlled environmental conditions (25 ± 2 °C, with a 12 h light/dark cycle). A commercially balanced diet and tap water were provided ad libitum for one week prior to the start of the experiment. The basal diet was formulated according to **Krishnakumari *et al.* (1979)**.

Chemicals

Indomethacin was purchased from SIGMA-ALDRICH (22 Abo Zar El-Ghafary St., from El-Tayaran St., Nasr City, Cairo, Egypt). Biochemical kits used to determine serum pH, total acidity, pepsin, mucin, reduced glutathione, catalase, malondialdehyde (MDA), and cyclooxygenase were obtained from the Bio-Diagnostic Chemical Company, Egypt.

Methods

Preparation of Sweet Potato Flour

Fresh sweet potatoes (*Ipomoea batatas*) were thoroughly washed to remove adhering soil and debris, peeled, rewashed, and subsequently blanched in a 0.25% sodium metabisulphite solution for 15 minutes. The tubers were then sliced and dried in

a Gallenkamp hotbox oven at 70 °C for 18 hours. The dried sweet potato chips were milled into flour as described by **Eke-Ejiofor and Beleya (2017)**, passed through a 60 mm mesh sieve to obtain uniform particle size, and stored in airtight containers until further use.

Preparation of Cracker formulations

Crackers were prepared following the method of **Manley (2001)**, with slight modifications. Wheat flour was partially replaced by sweet potato flour at 25%, 30%, 35%, and 40% **(Table 1)**. Wheat and sweet potato flours were mixed with sugar, salt, baking powder, and cumin, then combined with butter to obtain a uniform crumb. Water was gradually incorporated to form a firm dough, which was rolled to ~0.25-inch thickness and cut using metal cutters. The dough pieces were pierced with a fork and baked at 180 °C for 12 min until golden and crisp. After cooling at 25 °C for 15 min, samples were stored in airtight containers for further analyses.

Table (1) : Cracker formulations with sweet potato flour.

Ingredients (g)	Control	SPC(1)	SPC(2)	SPC(3)	SPC(4)
Wheat flour	100	75	70	65	60
Sweet potato flour	0.0	25	30	35	40
Butter	15	15	15	15	15
Water	60	60	60	60	60
Salt	5	5	5	5	5
Egg	5	5	5	5	5
Baking powder	3	3	3	3	3
Cumin	5	5	5	5	5
Sugar	40	40	40	40	40

- **C** = Control crackers without sweet potato flour (100g) whole wheat flour.
- **SPC1** = Crackers with 25g sweet potato flour.
- **SPC2** = Crackers with 30g sweet potato flour.
- **SPC3** = Crackers with 35g sweet potato flour.
- **SPC4** = Crackers with 40g sweet potato flour.

Analytical methods

Determination of chemical composition

The moisture, crude protein, fat, crude fiber, and ash contents of the prepared cracker samples were determined using established analytical procedures described by the **Association of Official Analytical Chemists [AOAC], (2005)**. The carbohydrate content was estimated by a difference of 100% after accounting for moisture.

Determination of *β*-Carotene

The *β*-carotene content of the prepared cracker samples was determined according to the method described by **Rodriguez-Amaya (2001),** Approximately (2g) of the homogenized sample was extracted with acetone and partitioned into petroleum ether. The petroleum ether layer was subsequently dried, concentrated, and purified using a chromatographic column. The absorbance of the *β*-carotene fraction was measured at (440nm) using a spectrophotometer and the concentration was calculated based on the standard equation with an absorption coefficient of 2592 for petroleum ether.

Determination of total Phenolics, Flavonoids, and Antioxidant Activity

The bioactive compounds and antioxidant properties of the prepared cracker samples were evaluated. Samples were extracted using 80% methanol and centrifuged at

8000 rpm at room temperature; the supernatants were used for all analyses. Total phenolic content (TPC) was determined using the Folin–Ciocalteu method **(Rodriguez-Amaya, 2001)**. Absorbance was measured at 760 nm, and results were expressed as mg gallic acid equivalents (mg GAE/100 g). Total flavonoid content (TFC) was measured by the colorimetric method **(Bakar *et al.*, 2009).** Absorbance was recorded at 510 nm, and values were expressed as mg quercetin equivalents milligrams of Quercetin Equivalent per 100 grams of sample (mg QE/100 g). Antioxidant activity (Radical scavenging activity) was assessed using the DPPH method **(Oms-Oliu *et al.*, 2009)**. Absorbance was read at 517 nm, and antioxidant activity was expressed as percentage inhibition. Total antioxidant capacity (TAC) was determined using the phosphomolybdenum method **(Bhardwaj *et al.*, 2015)**. Absorbance was measured at 695 nm, and results were expressed as mg ascorbic acid equivalents milligrams of Ascorbic Acid Equivalent per 100 grams of sample (mg AAE/100 g).

Sensory evaluation

Sensory attributes of the prepared cracker samples were evaluated using the method of **Olapade and Ogunade (2014)**. Fifty panelists including faculty members, graduate students, and undergraduates from the Faculty of Specific Education, Alexandria University (Egypt), assessed the appearance, color, texture, shape, smell, taste, and overall acceptability on a 9-point Hedonic scale (1 = dislike extremely; 9 = like extremely). Samples were coded and identically packaged to avoid bias, and potable water was provided between evaluations.

Biological methods

Experimental Animals and Physiological Measurements

Experimental design

After one week of acclimatization, thirty healthy male rats were randomly divided into five groups (n = 6). Gastric ulcers were induced in all groups, except the negative control, following the method of **Gohar and Zaki (2014)** by oral administration of indomethacin (30 mg/kg body weight). Animals were fasted for 24 h before treatment. **The replacement levels of sweet potato flour (25%, 30%, and 35%) were selected based on the best results obtained from sensory evaluation of crackers.** After ulcer induction, rats were fed daily for four weeks with a standard diet and prepared cracker samples according to the following groups:

- **Group 1 (C-):** Negative control, rats fed on standard diet + whole wheat crackers.

Gastric ulcers induced groups:

- **Group 2 (C+):** Positive control, rats fed on standard diet + whole wheat crackers.
- **Group 3: Rats** fed on standard diet + whole wheat crackers fortified with sweet potato (25g).
- **Group 4:** Rats fed on standard diet+ whole wheat crackers fortified with sweet potato(30g).
- **Group 5:** Rats fed on a standard diet + whole -wheat crackers fortified with sweet potato (35g).

At the end of the experiment (four weeks post-induction), body weight gain (BWG) and daily food intake of the rats were recorded throughout the experimental period to monitor their physiological responses to dietary supplementation. Body weight

gain (BWG) was calculated by subtracting the initial body weight from the final body weight of each rat during the experimental period:

BWG (g)=Final body weight (g)−Initial body weight (g)

After that Rats were sacrificed under ether anesthesia **(Morimoto *et al.*, 2002)**. The stomach was excised, rinsed and blotted dry. Gastric contents were collected, centrifuged at 3500 rpm for 15 min, and the clarified supernatant was used for further analysis **(Dai and Ogle, 1974)**. Stomach tissues were homogenized in ice-cold 100 mM phosphate buffer (pH 7.4) and centrifuged at 7000 rpm for 20 min, and the resulting supernatant was used for biochemical assays **(Ohkawa *et al.*, 1979)**.

Biochemical determinations:

The gastric pH was measured after centrifugation of gastric contents, and the clear supernatant was analyzed using a digital pH meter according to **Sivaraman and Muralidharan (2011)**. Total acidity was assessed by titration against 0.01 N NaOH to an endpoint of pH 7.4 **(Dai and Ogle, 1972)**. Pepsin activity in gastric juice was estimated spectrophotometrically at 578 nm using hemoglobin substrate as described by **Dai and Ogle (1972)**. Gastric mucin content was evaluated using Alcian Blue staining method following **(Bancroft and Gamble, 2008)** Lipid peroxidation (MDA) was determined by the thiobarbituric acid method **(Ohkawa *et al.*, 1979)**. Antioxidant status in gastric tissues was assessed through enzymatic assays, including reduced glutathione (GSH) and catalase **(Ding *et al.*; Han *et al.*, 2017)**. Superoxide dismutase (SOD), glutathione reductase (GSR), glutathione peroxidase (GPx), and glutathione-S-transferase (GST), providing a comprehensive evaluation of the tissue's oxidative defense mechanisms and Hydrogen peroxide(H_2O_2) according to **Beutler *et al.* (1963)**.

Histopathological examination of gastric

Stomach samples from different rat groups were fixed in 10% formal saline for 24 h, dehydrated in graded alcohols, cleared in xylene, and embedded in paraffin at 56 °C. Sections (4 µm) were prepared using a microtome, deparaffinized, and stained with hematoxylin and eosin according to **Bancroft and Gamble (2008)**. Histopathological alterations were evaluated under a light microscope and graded as: 0 = no change, 1 = mild, 2 = moderate, and 3 = severe **(Abd-Alla *et al.*, 2022)**.

4. Statistical analysis

Data analysis was conducted using IBM SPSS software version 23.0. Quantitative data was described using mean and standard deviation. Statistical significance was determined at the 5% level. To compare more than two groups, the F-test (ANOVA) was employed, followed by the Post Hoc test (LSD) for pairwise comparisons, as described by **Feeney (2016)**.

Result and discussion

Chemical Compositions of Crackers

The proximate compositions of whole wheat crackers enriched with sweet potato flour are displayed in **Table 2**. Protein and crude fat contents decreased with increasing levels of sweet potato flour supplementation, while ash, crude fiber, carbohydrate and β-carotene contents increased as the proportion of sweet potato flour increased. The protein and crude fat contents decreased from 15.11% and 9.01% in the control to 6.80% and 6.12% at 40% substitution, respectively. Conversely, the levels of ash, crude

fibre, total carbohydrate, and β-carotene exhibited substantial increases ($p \leq 0.05$), with values of 3.30%, 16.92%, 68.99%, and 15.67 µg/100 g, respectively, in comparison to 2.32%, 10.15%, 58.99%, and 0.43 µg/100 g in the control group. The increase in fibre and β-carotene is due to the elevated levels of non-starch polysaccharides and carotenoids in sweet potato flour. These findings align with prior research that documented analogous effects of sweet potato flour integration in baked goods. Replacing wheat flour with purple or orange-fleshed sweet potato flour markedly modifies the chemical composition, typically resulting in reduced protein and fat levels, while enhancing ash, fibre, and β-carotene content **(Nzamwita, 2012)**. The elevation of β-carotene noted in our research corresponds with previous findings indicating that orange-fleshed sweet potato is abundant in carotenoids, which directly enhance β-carotene concentrations in fortified products **(Silungwe, 2017)**. Moreover, increases in ash and fibre content have been associated with the nutritional value and possible health advantages of sweet potato flour, including enhanced digestion and cholesterol lowering **(Rosell *et al.*, 2024)**. Fluctuations in β-carotene concentrations may arise from factors such as cultivar, ripeness, harvesting, processing, and storage; however, the observed pattern of elevated β-carotene with greater sweet potato flour substitution in our study aligns with prior research **(Silungwe, 2017)**. Overall, the fortification with sweet potato flour enhanced the nutritional quality of crackers, significantly elevating β-carotene, ash, fibre, and carbs, while diminishing protein and fat content.

Table (2): Chemical composition of Crackers Whole Wheat Fortified with Sweet Potato Flour

Component (g/100 g, dry basis)	Control	SPC 25%	SPC 30%	SPC 35%	SPC40%	F	P	LSD 5%
Protein	15.11**^{a}±2.52	12.07 ^{ab} ±2.74	10.13 ^{bc} ±1.63	8.20 ^{cd} ±0.98	6.80 ^{d} ±0.57	9.022*	0.002*	3.553
Crude Fat	9.01 ^{a} ±1.60	8.20 ^{a} ±2.20	7.53 ^{a} ±1.90	7.0 ^{a} ±1.08	6.12 ^{a} ±0.72	1.447	0.289	3.000
Ash	2.32 ^{b} ±0.29	3.12 ^{ab} ±0.41	3.21 ^{a} ±0.35	3.24 ^{a} ±0.58	3.30 ^{a} ±0.62	2.264	0.134	0.881
Crude Fiber	10.15 ^{c} ±1.16	12.21 ^{bc} ±1.41	14.32 ^{ab} ±1.28	16.13 ^{a} ±1.91	16.92 ^{a} ±2.55	7.743*	0.004*	3.272
Total Carbohydrates	58.99^{c} ±0.77	64.26 ^{b} ±1.43	65.87 ^{ab} ±1.10	67.15 ^{ab} ±0.52	68.99 ^{a} ±3.92	11.383*	0.001*	3.680
β-carotene (µg/100 g)	0.43 ^{d} ±0.09	7.03 ^{c} ±0.81	9.34 ^{c} ±1.58	12.65 ^{b} ±1.99	15.67 ^{a} ±2.49	38.098*	<0.001*	3.072

****Every value represents the mean value ± SD of three determinations, Mean values in each row having different letter are significantly at P < 0.05.**

SPC: Sweet potato Crackers.

Phytochemicals content of Crackers

Table (3) shows that fortification with sweet potato flour significantly increased all phytochemical parameters compared to the control. Both TPC, TFC, TAC, and DPPH inhibition rose progressively with substitution levels, reaching 56.2 mg GAE/100 g, 34.71 mg quercetin/100 g, 8.91 mg ascorbic acid/100 g, and 65.0%, respectively, at 40% substitution versus 5.61, 3.5, 0.4, and 16.21 in the control ($p < 0.001$). This enhancement could be attributed to the richness of sweet potato flour in bioactive compounds, particularly phenolics, flavonoids, and carotenoids, which contribute directly to higher antioxidant activity.

These findings align with many prior studies indicating that sweet potato flour progressively increases the phytochemical content of baked goods. For example, sweet potato biscuits and breads enhanced with sweet potato flour showed substantial

increases in total phenolic content (TPC), total flavonoid content (TFC), total antioxidant capacity (TAC), and DPPH scavenging activity at elevated substitution levels **(Khongla *et al.*, 2024)**. Purple-fleshed sweet potato cultivars had the greatest phytochemical concentrations, with total phenolic content (TPC) values of 128.03 mg GAE/100 g and enhanced antioxidant activity relative to yellow cultivars **(Chintha *et al.*, 2023)**.

Furthermore, Djordjević et al. (2024) observed that the fortification of bread with OFSP significantly enhanced TPC and TFC values, ranging from 63.20 to 300.86 mg GAE/100 g d.b. Optimized composite breads exhibited total phenolic content (TPC) values 3.0-4.8 times more and total flavonoid content (TFC) levels 4.3-7.2 times greater than the controls, corroborating the trend identified in the present investigation.

The current data affirm that the incorporation of sweet potato flour improves the phytochemical profile and antioxidant capacity of crackers, aligning with previous research on various baked goods.

Table (3): Phytochemicals content of Crackers Whole Wheat Fortified with Sweet Potato Flour

Phytochemicals Composition	Control	SPC 25%	SPC 30%	SPC 35%	SPC40%	F	P	LSD 5%
TPC (mg GAE/100g)	5.61** ^{e} ±0.63	19.02 ^{d} ±1.54	36.43 ^{c} ±1.78	44.53 ^{b} ±2.99	56.2 ^{a} ±2.97	257.450*	<0.001*	4.099
TFC (mg quercetin /100g)	3.5 ^{e} ±0.29	10.6 ^{d} ±0.86	17.35 ^{c} ±1.20	24.56 ^{b} ±1.28	34.71 ^{a} ±2.24	246.983*	<0.001*	2.515
TAC (mg ascorbic acid /100g)	0.4 ^{d} ±0.08	4.01 ^{c} ±0.087	5.5 ^{bc} ±0.68	7.32 ^{b} ±1.47	8.91 ^{a} ±1.10	34.976*	<0.001*	1.804
DPPH (%)	16.21 ^{d} ±2.61	43.4 ^{c} ±3.79	50.8 ^{b} ±2.70	59.1 ^{a} ±4.04	65.0 ^{a} ±.16	75.920*	<0.001*	7.116

****Every value represents the mean value ± SD of three determinations, Mean values in each row having different letter are significantly at P < 0.05.**

SPC: Sweet potato Crackers. Phenolic content (TPC), total flavonoid content (TFC), total antioxidant capacity (TAC), and 2,2-Diphenyl-1-picrylhydrazyl scavenging activity

Sensory evaluation of crackers

The sensory attributes of whole-wheat crackers fortified with sweet potato flour are presented in **Table (4)** and **Figure (1)**. No notable variations were detected among the control, 25%, 30%, and 35% substitution levels regarding the majority of sensory attributes. At a 40% substitution level, all parameters:color, aroma, shape, flavour, texture, and overall acceptability exhibited a substantial decline ($p \leq 0.05$), with mean ratings of 5.18, 6.28, 6.33, 6.60, 6.53, and 6.58, respectively, in contrast to the control scores of 8.73, 8.40, 8.63, 8.75, 8.63, and 8.68. The current investigation found that substituting wheat flour with orange-fleshed sweet potato flour up to 35% did not significantly impact most sensory qualities, however a notable decrease was detected at 40% substitution. These findings align with **Mitiku *et al.* (2018)**, who determined that substituting purple sweet potato flour up to 35% preserved acceptable quality, however greater proportions diminished customer preference. **Leksrisompong *et al.* (2012)** reported that a 50% substitution adversely impacted taste, despite moderate colour acceptance. **Infante *et al.* (2017)** observed that biscuits fortified with 10–30% sweet potato flour were comparable to controls, while higher levels diminished acceptability. The 40% drop observed in the current study may be ascribed to pronounced alterations

in color and flavour linked to sweet potato flour, perhaps constraining consumer preference. Nevertheless, mild substitution (25–35%) yielded nutritional improvement, encompassing elevated levels of β-carotene, ash, fibre, and carbs, while maintaining sensory quality. The findings substantiate the viability of utilizing sweet potato flour to create nutritionally enhanced baked goods with satisfactory customer attractiveness.

Table (4): Sensory evaluation of Crackers Whole Wheat Fortified with Sweet Potato Flour

Samples	Control	SPC 25%	SPC 30%	SPC 35%	SPC40%	F	P	LSD 5%
Color	8.73 ^{a} ±0.50	8.60 ^{a} ±0.69	8.28 ^{a} ±0.88	7.40 ^{a} ±.63	5.18 ^{b} ±0.36	16.008*	<0.001*	1.197
Smell	8.40 ^{a} ±0.42	8.10 ^{a} ±0.40	8.23 ^{a} ±0.49	8.13 ^{a} ±0.26	6.28 ^{b} ±0.17	17.242*	<0.001*	0.686
Shape	8.63 ^{a} ±0.27	8.55 ^{a} ±0.48	8.30 ^{a} ±0.70	8.53 ^{a} ±0.50	6.33 ^{b} ±0.68	9.570*	0.002*	1.032
Taste	8.75 ^{a} ±0.86	8.18 ^{a} ±0.42	8.55 ^{a} ±0.69	8.20 ^{a} ±0.88	6.60 ^{b} ±0.11	4.979*	0.018*	1.241
Texture	8.63 ^{a} ±0.70	8.18 ^{a} ±0.96	8.40 ^{a} ±0.41	8.23 ^{a} ±0.68	6.53 ^{b} ±0.19	4.993*	0.019*	1.222
General Acceptance	8.68 ^{a} ±0.71	8.20 ^{a} ±0.27	8.52 ^{a} ±0.54	8.25 ^{a} ±0.17	6.58 ^{b} ±0.16	11.893*	0.001*	0.797

****Every value represents the mean value ± SD, mean values in each row having different letter are significantly at P < 0.05.**

SPC: Sweet potato Crackers.

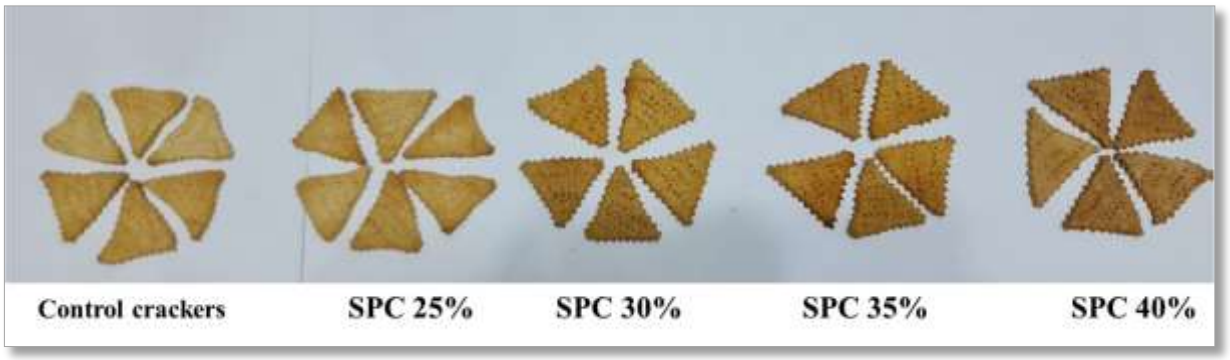


Figure (1): Sensory evaluation of Crackers Whole Wheat Fortified with Sweet Potato Flour

Effect of Crackers Fortified with Sweet Potato Flour on body weight of rats

Table 5 demonstrated the impact of sweet potato crackers (SPC) on body weight metrics in rats. No notable discrepancies were detected in the initial and final body weights between the groups. Nonetheless, body weight gain and daily food intake exhibited substantial variations ($p < 0.05$). The SPC 35% group had the greatest body weight gain (60.8 g) and food intake (2.90 g/day), whereas the positive control group demonstrated the lowest values of 38.5 g and 1.83 g/day, respectively. Intermediate levels were recorded in the SPC 25% and SPC 30% groups, however the negative control stayed within the normative range. The augmentation in body weight gain with elevated substitution levels may be ascribed to the enhanced nutrient density and palatability of sweet potato crackers, which elicited greater food consumption relative to the positive control. The current study demonstrated that the addition of sweet potato crackers markedly enhanced body weight gains and daily food consumption, with peak values observed at a 35% substitution relative to the positive control. The findings align with **Wu *et al.* (2019)**, who illustrated that rats consuming raw or cooked potato diets displayed markedly increased food intake and body weight gain relative to the positive control, indicating that potato-based supplementation enhances growth performance.

The current study demonstrated that the addition of sweet potato crackers markedly enhanced body weight gains and daily food consumption, with peak values observed at

a 35% substitution relative to the positive control. The findings align with **Wu *et al.* (2019)**, who showed that rats consuming raw or cooked potato diets displayed markedly increased food intake and body weight gain relative to the positive control, indicating that potato-based supplementation enhances growth performance. Likewise, **Akhtar *et al.* (2018)** noted that sweet potato peel extract influenced body weight in diabetic rats owing to its high dietary fibre content and low glycemic index, which prolong gastric emptying and modulate nutritional absorption. **Komarnytsky *et al.* (2011)**, emphasized that differences in protease inhibitor levels in potatoes may impact nutrition absorption and thus influence body weight results.

Table (5): Effect of Crackers Whole Wheat Fortified with Sweet Potato Flour on body weight parameters in rats

Groups	Initial weight (g)	Final weight (g)	Body weight gain (g)	Daily food intake (g/day)
C− (Normal control)	150.50** ^{b} ±4.97	204.0^{ab} ±5.96	53.50^{c}±2.61	2.55^{ab}±0.60
C+ (Positive control)	162.12 ^{a} ±6.55	200.62^{b} ±8.52	38.50^{d}±2.63	1.83^{c} ±0.17
SPC 25%	156.25^{ab} ±5.64	201.70 ^{ab}±4.67	45.50^{b}±1.41	2.17^{bc} ±0.25
SPC 30%	159.61^{ab}±6.20	204.20 ^{ab}±4.65	44.60^{b}±1.57	2.12^{bc} ±0.16
SPC 35%	152.45 ^{ab}±5.68	213.23^{a}±7.17	60.80 ^{a}±2.55	2.90^{a}±0.36
F	2.055	1.833	45.525*	4.365*
P	0.162	0.199	<0.001*	0.027*
LSD 5%	10.982	11.992	4.189	0.649

**** Data represent the mean± S.D. of observation from six rats, mean values in each column having different letter are significantly at P < 0.05**
C-: Negative control; C+: Positive control

Effect of Crackers on Gastric Parameters in Ulcerated Rats

Table (6) demonstrates the protective effect of sweet potato crackers (SPC) against gastric ulcer parameters in rats. Supplementation with SPC markedly elevated stomach pH (from 1.61 in the positive control to 3.10 at 35% SPC) and mucin production (from 0.37 g/mL to 0.76 g/mL), both nearing normal control values. Conversely, SPC markedly reduced total acidity (from 104.69 to 55.20 mEq/L) and lowered pepsin activity (from 3.24 to 1.91 g/mL), particularly at 30–35% substitution. These results indicate that SPC fortification promotes gastric mucosal protection by restoring mucus production, moderating acidity, and regulating proteolytic enzyme activity, thereby reducing ulcer severity. Consistent with the current findings, **Sayed *et al.* (2022)** found that pretreatment of rats with sweet potato juice significantly elevated gastric pH relative to the ulcer-induced group, hence affirming the protective effect of sweet potato against gastric acidity and ulcerogenesis. In the present investigation, indomethacin-treated rats (positive control) demonstrated the lowest stomach pH (1.61) and the highest pepsin activity (3.24 g/mL), indicating significant mucosal damage. Reports indicate that indomethacin, as a weak organic acid, increases hydrogen ion generation in the stomach mucosa, hence boosting pepsin activity and exacerbating ulcer severity **(Suleyman *et al.*, 2010)**. **Rengarajan *et al.* (2012)** noted a substantial elevation ($P < 0.05$) in gastric pH in rats administered sweet potato, ascribed to its abundant nutritional composition, which encompasses proteins, carbs, and vitamins. Furthermore, **Eissa *et al.* (2021)** indicated that sweet potatoes function as a natural antacid owing to their bioactive components, which contribute to the enhanced gastric pH and diminished acidity noted in the SPC-supplemented groups of this study. Additional evidence is

provided by **Pasha *et al.* (2022)**, who discovered that sweet potato polysaccharides had gastroprotective properties by increasing mucin secretion and diminishing oxidative stress indicators in ulcer-induced mice. Similarly, **Sun *et al.* (2024)** demonstrated that dietary anthocyanins from sweet potatoes mitigated ethanol-induced gastric damage by inhibiting pepsin hypersecretion and maintaining gastrointestinal mucosal integrity. The results align with the notable enhancement in mucin secretion (0.76 g/mL at 35% SPC) and the normalization of pepsin activity (1.91 g/mL) recorded in this study. These results confirm that SPC fortification, especially at 30–35% substitution, exerts a gastroprotective role by lowering gastric acidity, regulating pepsin activity, and restoring mucin secretion, which collectively maintain gastric mucosal defense mechanisms and reduce ulcer severity.

Table (6): Effect of Crackers on Gastric (pH, Acidity, Mucin, and Pepsin) in Ulcerated Rats

Groups	pH	T. Acidity (mEq/L)	MUCIN (g/mL)	PEPSIN (g/mL)
C− (Normal control)	3.33 ^{a} ±0.22	47.84 ^{d} ±5.65	0.81 ^{a}±0.07	1.74^{b} ±0.27
C+ (Positive control)	1.61^{c} ±0.37	104.69 ^{a}±8.15	0.37 ^{c} ±0.04	3.24 ^{a} ±0.74
SPC 25%	2.20^{b} ±0.19	73.10 ^{b}±3.16	0.57 ^{b} ±0.08	2.71 ^{a} ±0.41
SPC 30%	2.85^{b} ±.26	62.35 ^{c} ±4.53	0.67 ^{b} ±0.05	2.14 ^{b} ±0.26
SPC 35%	3.10 ^{a} ±0.16	55.20 ^{d} ±2.56	0.76 ^{a}±0.06	1.91^{b} ±0.11
F	24.556*	54.644*	27.056*	6.606*
P	<0.001*	<0.001*	<0.001*	0.007*
LSD 5%	0.463	9.796	0.109	0.785

**** Data represent the mean± S.D. of observation from six rats, mean values in each column having different letter are significantly at P < 0.05**

Antioxidant enzymes in tissues of the stomach in experimental rats

Table(7) demonstrated a considerable disruption in the antioxidant state of ulcerated rats (C+), with all enzymatic activities markedly reduced in comparison to the normal control group (C−). Specifically, CAT decreased from 6.10 ± 0.12 u/g in group C− to 1.30 ± 0.21 u/g in C+, but SOD reduced from 610 ± 5.39 u/g to 233 ± 5.99 u/g. Likewise, GSH decreased significantly from 336 ± 3.18 mmol/g to 163 ± 3.76 mmol/g, while GSR declined from 25.65 ± 2.73 u/g to 6.45 ± 0.43 u/g. The same trend was observed in GPx and GST, which dropped from 65.13 ± 1.29 and 306.54 ± 7.26 u/g to 30.32 ± 2.08 and 175.13 ± 6.42 u/g, respectively. On the other hand, supplementation with SPC improved antioxidant defense in a dose-dependent manner. The SPC 25% group demonstrated modest recovery, whereas the SPC 30% and SPC 35% groups displayed substantial increases towards the normal control levels. For example, CAT attained 5.65 ± 0.39 u/g, SOD 580 ± 6.70 u/g, GSH 318 ± 5.47 mmol/g, and GST 286.24 ± 6.80 u/g in SPC 35%, signifying a restoration of enzyme activity around normal levels. These findings confirm that SPC enhanced the antioxidant capacity of gastric tissue, which may be attributed to the synergistic effect of β-glucan and protein in scavenging free radicals and reinforcing cellular defense systems. Consistent with the current findings, numerous studies have emphasized the significance of sweet potato and its bioactive constituents in rehabilitating antioxidant defense in the context of stomach damage. **Panda and Sonkamble (2012)**, indicated that pretreatment with sweet potato juice markedly enhanced gastrointestinal antioxidant enzyme activity (SOD, CAT, and GSH) in ulcer-induced rats, aligning with the recovery observed in the

SPC-fed groups of this investigation. **Chang *et al.* (2021)**, similarly found that sweet potato supplementation enhanced oxidative equilibrium by decreasing lipid peroxidation and augmenting enzymatic defense mechanisms, attributing this impact to its abundant vitamins and polyphenolic substances.

Recent data corroborates these findings. **Su *et al.* (2023)**, demonstrated that sweet potato polysaccharides safeguarded the stomach mucosa against ethanol-induced damage by markedly restoring levels of CAT, SOD, and GPx, while concurrently decreasing (MDA). Similarly, **Cipriano (2016)**, demonstrated that sweet potato anthocyanins mitigated oxidative stress in gastric tissue by augmenting GSH and GST activities, resulting in enhanced mucosal integrity. Moreover, **Panda and Sonkamble (2012)**, indicated that β-carotene-enriched sweet potato extract enhanced antioxidant enzyme activity and inhibited ROS production in ulcer-induced rats, which corresponds with the notable recovery in CAT (5.65 u/g), SOD (580 u/g), and GSH (318 mmol/g) recorded in the SPC 35% group of the current study. Moreover, **Maqsood *et al.* (2025)** emphasized that dietary flavonoids from sweet potatoes serve as effective free radical scavengers, mitigating oxidative damage and preserving redox equilibrium in gastrointestinal tissue. The findings validate that the antioxidant properties of sweet potato arise not alone from its vitamin C and β-carotene levels but also from its synergistic polyphenolic composition, which modulates enzymatic activity and enhances the endogenous antioxidant system.

The notable restoration of enzymatic activities (CAT, SOD, GSH, GSR, GPx, and GST) in the SPC 35% group strongly indicates that SPC fortification enhances gastric antioxidant defense by neutralizing free radicals and strengthening cellular protective mechanisms, thus diminishing oxidative stress and ulcer severity.

Table (7): Effect of Crackers on Gastric Antioxidant Enzyme Activities in Rats.

Groups	CAT (u/g tissue)	SOD (u/g tissue)	GSH (mmol/g tissue)	GSR (u/g tissue)	GPx (u/g tissue)	GST (u/g tissue)
C− (Normal control)	6.10** ^{a}±0.12	610 ^{a} ±5.39	336 ^{a}±3.18	25.65 ^{a}±2.73	65.13 ^{a}±1.29	306.54 ^{a}±7.26
C+ (Positive control)	1.30 ^{d} ±0.21	233^{e} ±5.99	163^{e} ±3.76	6.45^{c} ±0.43	30.32 ^{d}±2.08	175.13^{d} ±6.42
SPC 25%	3.30 ^{c}±0.38	391^{d} ±6.61	248^{d} ±4.94	13.35^{b} ±1.76	32.78^{d} ±2.63	224.14^{c} ±7.05
SPC 30%	4.15^{b} ±0.59	475^{c} ±8.10	295^{c} ±5.42	16.12^{b} ±1.49	41.87 ^{c} ±3.17	233.65^{c} ±5.60
SPC 35%	5.65 ^{a}±0.39	580 ^{b}±6.70	318 ^{b}±5.47	21.24^{b} ±2.87	57.89^{b}±4.69	286.24^{b} ±6.80
F	79.650*	1589.250*	666.968*	38.441*	78.777*	185.335*
p	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
LSD 5%	0.705	12.464	3.876	8.444	5.645	12.524

CAT: Catalase, **SOD:** Superoxide dismutase, **GSH:** Glutathione, **GSR:** Glutathione reductase, **GPx:** Glutathione peroxidase, **GST:** Glutathione-S-transferase.

** Data represent the mean± S.D. of observation from six rats, mean values in each column having different letter are significantly at $P < 0.05$

Free radicals of stomach tissues in experimental rats

The levels of oxidative stress biomarkers malondialdehyde (MDA) and hydrogen peroxide (H_2O_2), in gastric tissues of experimental rats are presented in **Table 8** shows that gastric ulceration in the C+ group markedly increased oxidative stress markers, with MDA and H_2O_2 values reaching 9.75 ± 0.68 nmol/g and 1.47 ± 0.15 mM/g, respectively, compared to the normal control (C−) which recorded the lowest levels (1.40 ± 0.07 and 0.08 ± 0.001, respectively). In contrast, supplementation with sweet potato cookies (SPC) significantly reduced these elevated levels in a dose-dependent fashion. SPC 35% had the most pronounced reduction, with MDA and H_2O_2 levels

declining to 3.0 ± 0.26 nmol/g and 0.50 ± 0.02 mM/g, respectively, approaching the values of the normal control group. The observed reduction in free radicals with SPC intake could be explained by the presence of natural antioxidants such as β-carotene, phenolic compounds, and dietary fibers, which enhance the radical-scavenging activity and protect gastric tissues from oxidative damage. Prior studies indicate that sweet potatoes, especially purple kinds, exhibit potent antioxidant properties by markedly decreasing oxidative stress indicators such (MDA). Supplementation with purple sweet potato jelly for 14 days resulted in significant reductions in MDA levels in type 2 diabetic rats, with drops varying from −4.08±0.54 to −6.56±0.50 nmol/ml according on dosage **(Noviati *et al.*, 2019)**. Purple sweet potato anthocyanin extracts at dosages of 50–100 mg/kg effectively decreased blood MDA levels in hyperglycemic rats following 35 days of therapy **(Herawati *et al.*, 2020)**. A separate study demonstrated that purple sweet potato extract mitigated exercise-induced oxidative stress, shown by a notable decrease in MDA levels and an elevation in superoxide dismutase activity in rats undergoing intense exercise **(Sholikhah *et al.*, 2018)**. The findings align with **Altaf *et al.* (2023)**, who indicated that antioxidant-rich substances significantly reduce MDA levels and bolster protective mechanisms against stomach ulceration. Consistent with other research, the current findings indicate that fortification with sweet potato, especially at a 35% substitution level, led to the most significant reduction in MDA levels compared to the 30% level, underscoring a dose-dependent antioxidant impact. Significantly, to our knowledge, no prior studies have systematically demonstrated that elevating the substitution amount beyond 30% consistently enhances protective effects. This highlights the originality of the present study in determining 35% sweet potato integration as the ideal level for improving both antioxidant status and gastrointestinal protection.

Table (8): Effect of Crackers on Gastric Free Radical in Rats.

Groups	MDA (nmol/g tissue)	H_2O_2 (mM/g tissue)
C− (Normal control)	1.40** ^{d} ±0.07	0.08^{e} ±0.001
C+ (Positive control)	9.75 ^{a}±0.68	1.47 ^{a}±0.15
SPC 25%	5.30 ^{b} ±0.90	0.98^{b} ±0.07
SPC 30%	4.90 ^{b} ±0.60	0.76^{c} ±0.05
SPC 35%	3.0^{c} ±0.26	0.50^{d} ±0.02
F	87.459*	127.395*
P	<0.001*	<0.001*
LSD 5%	1.096	0.150

MDA: Malondialdehyde, H_2O_2: Hydrogen peroxide.

** Data represent the mean± S.D. of observation from six rats, mean values in each column having different letter are significantly at P < 0.05

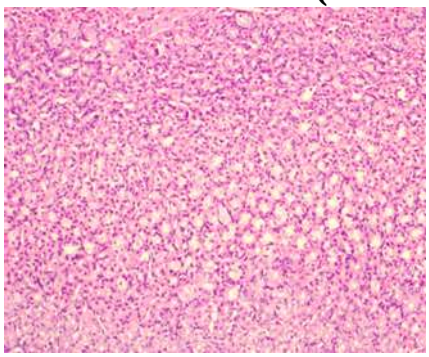
Histopathological examination of stomach tissues

The results depicted in **(photo 1)** illustrate the histological examination of stomach mucosa in rats with indomethacin-induced ulcers. The stomachs of rats in the group C- exhibited normal histoarchitecture of the gastric layers, devoid of any ulcerative changes **(photo1- A)**. Conversely, the group C+ demonstrated significant histological damage marked by widespread mucosal necrosis, submucosal oedema, and infiltration of inflammatory cells **(photo1- B)**. Analysis of gastric tissue from rats administered crackers enriched with 35% sweet potato flour (SPC 35%) demonstrated significant

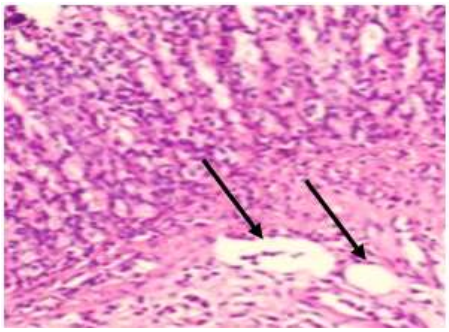
enhancement, exhibiting nearly normal gastric architecture with slight submucosal oedema in certain areas, while other regions displayed minimal histological abnormalities **(photoe 1-C)**.

In table(9)the histological assessment of gastric lesion scores showed that the group C− (Normal control) had intact gastric mucosa without any ulcerative lesions. The C+ group (Positive control) displayed extensive haemorrhagic gastric lesions affecting significant portions of the glandular mucosa. The SPC 35% group exhibited significant protection against indomethacin-induced gastric ulcers, presenting nearly normal mucosal appearance with very minor superficial alterations in restricted regions.

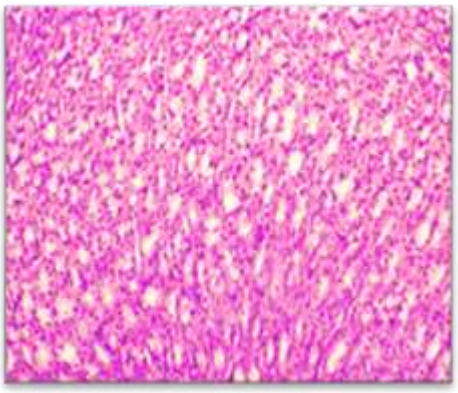
The findings of our study align with existing literature about the preventive properties of sweet potato as a pretreatment for stomach ulcers. Research on white sweet potato flour in a rat ethanol ulcer model demonstrated that it decreased inflammation and ulceration while maintaining stomach mucosal folds **(Pasha *et al.*, 2022)**. A carotenoid extract from orange sweet potato conferred protection, evidenced by a notable decrease in ulcer area, alongside diminished inflammation indicating the histological protection of carotenoid **(Bae *et al.*, 2021)**. Additional research utilising potato extracts in aqueous or ethanolic solutions within models of aspirin, stress, or alcohol-induced ulcers corroborates that the dietary or therapeutic application of sweet potato enhances mucosal tissue, diminishes morphological and haematological damage, and ameliorates oxidative markers **(Pasha *et al.*, 2022)**. A carotenoid extract from orange sweet potato was administered at a dosage of 100 mg/kg, resulting in approximately 78.1% ulcer prevention compared to the positive control **(Bae *et al.*, 2021)**. Thus, we can regard the use of 35% SPC in fortified crackers as a preventive measure that beneficially influences the integrity of the stomach mucosa when subjected to a trigger like indomethacin **(Olatunji, 2019)**.



A- Control(-)



B- control (+)



C- SPC(35%)

Photo (1.A-C). Photomicrograph of stomach tissues of rats

Table (9): Effect of the lesion score from the histological investigation

Histopathological lesion	Necrosis of gastric mucosa	Inflammatory cells infiltration	Edema
C− (Normal control)	-	-	-
C+ (Positive control)	+++	+++	+++
SPC ٣5%	+	-	-

Nil (-) = no lesions, + = mild lesion in less than 15% of examined samples, ++ = moderate lesion records of 16- 35 % of examined samples, +++ = severe lesion records more than 35% of examined samples.

Photo (2): Macroscopical appearance of gastric ulcers in rats' groups

Conclusion

Orange-fleshed sweet potato (OFSP) is abundant in β-carotene and bioactive chemicals, rendering it a promising functional dietary component. This research assessed the nutritional, sensory, and therapeutic properties of OFSP-fortified crackers in relation to indomethacin-induced stomach ulcers in rats. The findings indicated enhanced nutritional quality and gastroprotective properties, proposing OFSP (35%) crackers as a natural, economical dietary approach for ulcer care.

Ethical Approval

All study experiments were ethically approved by the Scientific Research Ethics Committee from the University of Alexandria, Animal Ethics Committee, Faculty of Medicine (**Approval no. 2025, SREC 0307531**).

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