JMBFS

Journal of Microbiology, Biotechnology and Food Sciences

International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

COMPOSITIONAL ANALYSIS, FUNCTIONAL PROPERTIES AND MICROSTRUCTURE OF COOKIES FORTIFIED WITH OLIVE LEAVES POWDER

Muhammad Shahid[1], Ali Muhammad[1], Muhammad Faiq[1]*

Address(es):
[1] The University of Agriculture Peshawar, Faculty of Nutrition Sciences, Department of Food Science and Technology, 25130, Peshawar, Pakistan.

*Corresponding author: alizypher@aup.edu.pk

https://doi.org/10.55251/jmbfs.12215

ARTICLE INFO

Received 28. 12. 2024
Revised 23. 6. 2025
Accepted 25. 9. 2025
Published 1. 10. 2025

Regular article

OPEN ACCESS

ABSTRACT

Olive leaves (OL) are a valuable source of minerals, fibers, and bioactive compounds with functional properties. The study aimed to develop fortified cookies with olive leaves powder (OLP) at varying concentrations (0, 20, 40, 60, 80, and 100 g kg^{-1} flour). Fine wheat flour (FWF), OLP and composite flours were analyzed for proximate composition, mineral content, functional properties and SEM analysis. Fortified cookies were evaluated for physicochemical, sensory, mineral, and microstructural attributes. Results showed that OLP contains high concentrations of ash, fiber, fat, calcium, iron, and zinc but lower moisture, protein, nitrogen-free extract (NFE), and potassium as compared to FWF. Functional properties such as water and oil absorption capacity were high in OLP, while swelling, foaming capacity, and foaming stability were lower in OLP. In composite flours, increasing OLP levels significantly reduced wet gluten from 30.02% to 17.97% and dry gluten from 9.10% to 6.84%. SEM analysis revealed irregular protein matrices with large granules of starch, and rough fiber structures. As the concentration of OLP increased in fortified cookies, a significant reduction was observed in width, spread ratio and NFE content while increase was observed in thickness, hardness, moisture, ash, fiber, fat, protein, and minerals contents. Sensory evaluation indicated that cookies fortified with 6% OLP were highly acceptable, offering enhanced nutritional benefits and prolonged shelf life.

Keywords: Olive leaves powder, functional properties, fortified cookies, SEM analysis, sensory evaluation

INTRODUCTION

Food fortification is a strategy that employs locally available and accessible resources, either plant-based or animal-derived, containing significant levels of essential micronutrients, to enhance the nutritional value of another food (**Uvere *et al*., 2010**). This approach supports economic growth by fostering the utilization of sustainable local resources, promoting self-reliance, and generating market opportunities for locally produced foods (**Riaz *et al*., 2022; Burchi *et al*., 2011**).
The olive leaves, pomace, mill wastewater and olive stones are considered as the waste or byproduct of the olive (**Gullón *et al*., 2020**). Olive leave are a rich source of fiber content, minerals, antioxidant, flavonoids and phenolic content (**Asmaey *et al*., 2024**). Whole leaves of olive and their extracts are commonly utilized as food supplements. Olive leaf extracts can be utilized as natural additives in food for their healthy and technological properties, with the objective to develop functional foods and to enhance the shelf-life of the product (**Difonzo *et al*., 2019**).
The chemical composition of olive leaves varies depending on several factors, including olive cultivar, climatic conditions, tree age, and wood content. Olive leaves contain 76.4-92.7g/100g of organic matter, 6.31-10.9g/100g of low levels of crude protein, adequate number of amino acids (89.9 g/100 g total nitrogen) and non-protein nitrogen associated with the cell wall is significant yet variable, accounting for 35.4-49.2g/100g of total nitrogen. Similarly, olive leaves contain 2.28-9.75g/100g of crude fat (**Rahmanian *et al*., 2015**).
The scientific community has paid special attention to utilizing olive wastes and byproducts such as leaves as they are rich in bioactive chemicals that can improve the functional qualities of packaging systems and lengthen the shelf life of food (**Selim *et al*., 2022**).
Cookie is a small sweet taste cereal-based baked food. They are formed from dough of wheat flour (**Miller, 2016; Manley, 2011**). Cookies are prepared by mixing certain ingredients such as wheat flour, sugar, baking soda, eggs, water, ghee and salt and are blended in a mixer in a specific ratio and kneaded by hand or machine to get find dough. The baking sector also enhances its production with the passage of time worldwide in last decades like other sectors by producing certain verities of baked goods (**Anjali *et al*., 2019**). The olive leaves are ever green leaves and is cultivated in more than 41 nations. The economic importance of the olive dates backs to the period of Bronze Age (3600 BC) (**Barazani *et al*., 2023**). The study was designed to prepare cookies with fortification of olive leaves powder, in order to enhance the nutritional, functional and antioxidant capacity of prepared cookies.

MATERIAL AND METHODS

Fine wheat flour (FWF) of Persabak variety was purchased from new Ahmad flour mill khazana sugar mill road, Peshawar. Olive leaves (OL) of Kalamata variety were obtained from the olive orchid of Agriculture Research Institute (ARI) Tarnab Peshawar. Olive leaves were pretreated, dried and grinded to produce powder using electric grinder (**Ewulo *et al*., 2017**). The olive leaves powder (OLP) was passed through sieve (50 mesh) to get uniform particle size. The prepared FWF and OLP was stored in clean polyethylene bags.

Preparation of Cookies

Cookies were prepared according to the standard method of **Riaz *et al*., (2021)** with a little modification in the spreading of dough sheets and formation of uniform cookies size, while baking time and temperature were remains constant. Ingredients for preparation of cookies were FWF (500g), grinded sugar (250g), Shortening (250g), egg (3 No's), baking powder (5g) and Baking Soda (5g). Treatments were prepared by replacing FWF with OLP in different proportions such as 2, 4, 6, 8 and 10% respectively.

Proximate composition

Moisture, ash content, crude fiber, crude protein, crude fat and NFE content of FWF, OLP and fortified cookies were analyzed by the method of **AACC (2010)**.

Mineral analysis and gluten content

Mineral content of FWF, OLP and fortified cookie were determined by atomic absorption and spectrophotometer with the standard method of **AACC (2010)**. Glutomatic instrument was used to measure the gluten content of the dough according to the standard method for gluten determination (**AACC, 2010**). The content left on the sieve after centrifugation is gluten Index (GI). Dry gluten was obtained by drying of wet gluten. The value of dry and wet gluten was recorded in the percentage.

Functional Properties

Water and oil absorption capacity were determined by the method of **Chandra *et al*., (2014)** was used.

Swelling power

Swelling power of FWF and OLP were determined by the method as reported by **Qazi *et al.*, (2014)**.
Swelling power = (Weight of sediment)/(Weight of flour-weight of dried supernatant) ------Eq-1

Foaming Capacity (FC) and Foaming Stability (FS)

The foam capacity (FC) and Foam stability (FS) was determined with certain modification by using the method used by **Narayana and Narasinga (1982)**.
Foam Capacity (%) = (VA-VB)/VB x 100 ----------Eq-2
Where, VA = Volume of foam after whipping, VB = Volume of foam before whipping
Foam Stability (%) = (VA-VB)/VB x 100 -----------Eq-3

Physical Characteristics and Scan Electron Microscopy (SEM) Analysis

Fortified cookies were analyzed for thickness, width, spread ratio and hardness using the method of **AACC (2010)**, While Scan Electron Microscopy Model No. SM5910, JEOL, made in Japan was used for SEM analysis.

Color analysis

Color of the fortified cookies were carried out by using Hunter Lab (Colorimeter) fitted with optical sensor (Hunter Associates Laboratory Inc., Reston, VA, USA) on the basis of CIE L*, a*, b* color system. L* values measure black to white (0–100), a* values measure redness or greenness when positive, and b* values measure yellowness when positive (**Aljobair, 2022**).

Sensory Evaluation of Cookie

Sensory evaluation of fortified cookies was determined by the method of **Larmond (1997)** using 9-point hedonic scale by semi trained judges from faculty and students of the department of Food Science and Technology. The data were taken in triplicate and mean score value of judges were determined.

Statistical Analysis

All the sample were taken in triplicate and were analyzed statistically by Statistix 8.1 and R-studio software. Significance level within the treatments, was determined by Analysis of variance (ANOVA) with LSD test at $p \leq (0.05)$ using CRD design with the standard method of **Steel *et al.*, (1997)**. Origin 2024b software and MS Excel was used for graphical representation of data and standard deviation.

RESULTS AND DISCUSSION

Proximate composition, mineral content and functional properties of FWF and OLP

Proximate composition of both FWF and OLP are shown it Table 1. Results revealed that OLP contains moisture content (8.03%), Ash (5.23%), protein (10.28%), fiber (55.65%), fat (3.60%) and NFE (17.79%) while that of FWF were 11.15% moisture, 1.34% ash, 12.48% protein, 2.40% fiber, 1.49% fat and 71.14% NFE content. Results showed that OLP contain considerable amount of fiber, fat and ash content as compared with FWF. **Muhammad *et al.*, (2023)** also analyses FWF for moisture content (11.01%), protein (10%), ash (1.34%), fat (1.06%) and NFE (74.43%) while moisture content (13.38%) at of dried olive leave at 40 ^{o}C temperature was determined by **Núñez-Gómez *et al.*, (2023)**. This difference between the moisture range of both FWF and OLP is because of different nature, drying condition, humidity and weather condition as well. The higher ash content in food sometimes is not suitable for making bread because the dough volume is reduced. But in case of bakery such as cookies, biscuit and pasta higher ash food are more appealing in term of sensory properties (**Miller, 2016**).

Table 1 Proximate composition, mineral content and functional properties of FWF and OLP

Treatment	**Moisture** (%)	**Ash** (%)	**Protein** (%)	**Fiber** (%)	**Fat** (%)	**NFE** (%)
FWF	11.15 ± 0.05	1.34 ± 0.06	12.48 ± 0.41	2.40 ± 0.44	1.49 ± 0.03	71.14 ± 0.50
OLP	8.03 ± 0.33	5.23 ± 0.25	10.28 ± 1.08	55.65 ± 0.36	3.60 ± 0.65	17.79 ± 1.78
Mineral content (mg/100g) of Fine Wheat Flour and Olive Leaves Powder						
	Ca	**K**	Fe	Zn		
FWF	4.45±0.03	33.92±0.01	0.047±0.001	0.260±0.65		
OLP	15.30±0.05	23.12±0.05	28.00+0.05	21.52±0.02		
Functional properties of FWF and OLP						
	WAC (%)	**OAC (%)**	**SP (%)**	**FC (%)**	**FS (%)**	
FWF	8.35±0.02	5.80±0.12	8.80±0.16	12.85±0.08	8.95±0.02	
OLP	33.16±0.11	12.25±0.07	6.20±0.26	0.02±0.02	2.21±0.12	

FWF=fine wheat flour, OLP=Olive leaves powder, WAC: water absorption capacity, OAC, oil absorption capacity, SP, swelling power, FC, foaming capacity, FS, foaming stability, along with a standard deviation (±SD).

The value of crude fiber for olive leave powder in previous study was recorded as 10.02% (**Cayan and Erener 2015**). Similar studies were also carried out on the fiber content of olive leaves powders which were 57.90% and 54.08% respectively (**Shokery *et al.*, 2017; Faccioli *et al.*, 2021**). The fiber rich food products are considered to be beneficial as they are helpful in reducing the risk of certain harmful diseases like diabetes, heart diseases, obesity and cancer (colorectal) (**Liu *et al.*,2011**). The higher fiber content in the OLP make it as a beneficial ingredient for baking of cookies in its formulation. **Faccioli *et al.*, (2021)** also measured the value of dried olive flour and they observed the fat of 1.60% and 8.80% while NFE (22.42%). As olive leave is highly nutritive in term of containing rich protein, fiber, fat and carbohydrates which make a food product a functional food.

Mineral content of FWF and OLP

Minerals of FWF were Ca (4.45), K (33.92), Fe (0.047) and Zn (0.260) while OLP were Ca (15.30), K (23.12), Fe (28) and Zn (21.52) as shown in Table 1. Results showed that OLP contain high amount of Ca, Fe and Zn as compared to FWF. **Muhammad *et al.*, (2023)** also analyzed FWF for mineral analysis such as Ca 4.42 mg/100 g, 33.91 mg/100g of potassium and Fe (0.044 mg/100g). De-Oliveira *et al.,* (2023) worked on the various varieties of the olive leaves and analyzed the leave for macro and micro nutrients such as Ca (8.04 to 15.29 mg/100g), K (23.12 mg/100g), 22-31 mg/100g of Fe content and 15-62 mg/100g of Zn content. Calcium and potassium are the important micronutrient and plays a key role in the growth, formation of bones (**Janati *et al.*, 2012**). Lalas *et al.,* (2017) showed the level of Zn up to 3.8mg/100g of the dry powder. Meanwhile common results were also shared by **Hassanein (2018)** which was 2.6-5.8mg100^{-1} g).

Functional properties of FWF and OLP

Functional properties of FWF and OLP shows its suitability for application in various baked goods. Results showed that the FWF has less water absorption capacity 8.38%, Oil absorption capacity 5.85% and have higher swelling power 8.80%, foaming capacity (FC) 12.85% and foaming stability (FS) 8.95 in contrast to the OLP which showed higher WAC (33.16%) and OAC (12.25%) as shown in Table 1. Results showed that swelling power of OLP was 6.18%, FC was 06.02% and FS were 2.21% respectively. Higher level of WAC of the OLP is due to a fibrous nature which absorbs more water whereas the FWF have lower level of WAC because of the bran which is removed during the refining process (**De-Oliveira *et al.*, 2023**). As OLP have lower carbohydrates and higher fiber level so that its WAC is also higher (**Kinsella 1979**). Lower WAC is due to rigid structure of starch molecules while high WAC means loosely compact structure of starch (**Dauda *et al.*, 2018**). FWF exhibit lower WAC than whole wheat flour (WWF) because of having low quantity of bran and germ (**Riaz *et al.*, 2022**).
Oil absorption capacity (OAC) of the flour is due to its ability to hold oil. This property of FWF and OLP gives indication that at which rate the protein binds with the added fat in the formulations (**Singh *et al.*, 2005**). The binding capacity of OLP is higher because of lower protein but higher fiber content than FWF. While the flour has low hydrophobic proteins which show superior binding of lipids (**Adeleke and Odedeji 2010**). OAC is important parameter of flour as it imparts flavor and texture to the bakery products (**Kumar *et al.*, 2011**).
Swelling capacity also played a key role in the formulation of the baked goods like, pasties, cakes and cookies etc. Swelling power of the product is due to the bonding of water molecules by the component of starch such as amylose and amylopectin in certain ratios (**Rasper *et al.*, 1974**). Non-Significance difference was observed in the SP of FWF and OLP. FWF shows lower SP (**Kaur *et al.*, 2012**) due to

existence of bran and germ portion. SP is also dependent upon the accessibility of water, heat, polysaccharide (starch) and protein (**Sui *et al.*, 2006**). As the SP depends upon the carbohydrates and other factors so the lower level of SP of OLP is due to less amount of carbohydrates and protein in the OLP.

Foaming capacity (FC) is the ability of material to give foam after thoroughly shaking or mixing. The foaming capacity and stability of the product is due to its composition such as protein content, starch and other surface-active compounds (**Appiah *et al.*, 2011**). Results showed that foaming capacity of FWF was 12.85% while that of OLP was 6.02% which lower than that of FWF. By using olive leave extract (OLE) in the egg showed enhancement in the FC initially but after a while the FC level starts to decline (**Godswill 2019**). The foaming capacity of OLP was less in comparison to that of FWF because of having less protein content (**Aliyari *et al.*, 2021**).

Foaming Stability (FS) is also important factor for evaluating the foam of any substance. Increasing the level of blending with other flour will decrease the foaming stability of flour but in case of FWF, its stability doesn't decline and remained constant (**Chandra *et al.*, 2014**). Foaming stability is inversely proportional to foaming capacity (**Chandra *et al.*, 2014**). Similarly using olive leave extract in the egg increases the FS (**Aliyari *et al.*, 2021**).

Scan Electron Microscopy (SEM) of FWF and OLP

The microphotograph of FWF is shown in Figure-1a and figure-1b. it showed a lentil look alike starch granules with multiple sizes distributed throughout the flour. Portion of protein embedded into the granules of starch. In some images irregular shapes such as disk and elongated granules has also been observed (**Gutierrez *et al.*, 2002, Saifullah and Qazi 2019**). In some images starch granules are embedded in protein matrix as shown in Figure 1a (**Parda and Aguilera, 2011**).

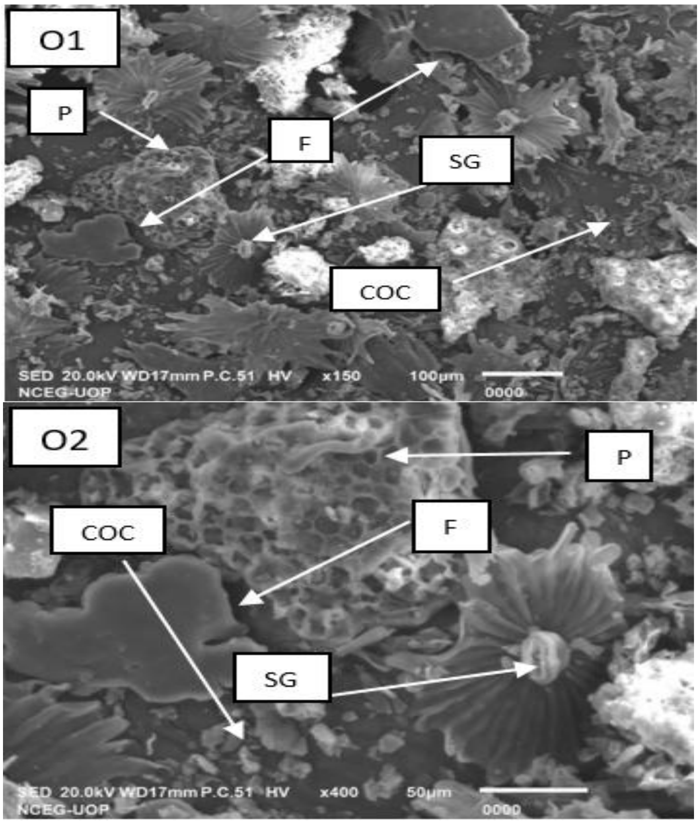
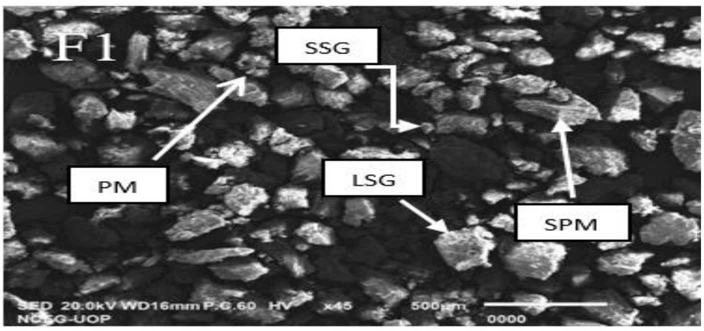


Figure 1a Micrograph of FWF and OLP where F1 & F2 shows the micrograph of FWF and O1 & O2 shows the micrograph of OLP. SSG: smaller starch granules, PM: protein matrix, LSG: larger starch granules, SPM: starch protein matrix, F: fiber, P: protein and COC: calcium oxalate crystal



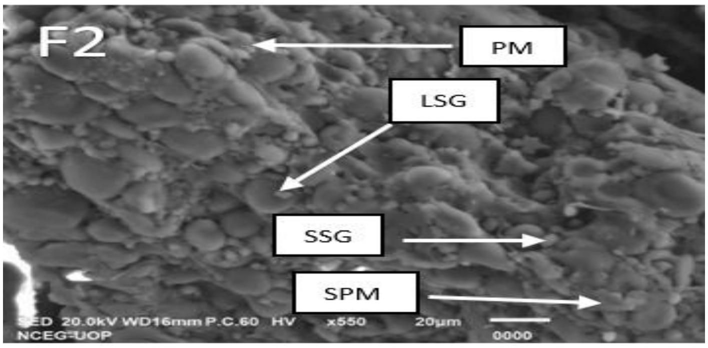


Figure 1b Micrograph of FWF and OLP where F1 & F2 shows the micrograph of FWF and O1 & O2 shows the micrograph of OLP. SSG: smaller starch granules, PM: protein matrix, LSG: larger starch granules, SPM: starch protein matrix, F: fiber, P: protein and COC: calcium oxalate crystal.

Micrograph for OLP is shown in the Figure 1a and 1b. The structure in the center resembles a flower-like formation, which could be due to particles aggregating into clusters or a natural morphology of specific compounds or cell fragments within the powder. Olive leaves contain various components such as fibers, waxes, and bioactive compounds, and processing them into powder can lead to the formation of these distinct structures. **Riaz *et al.*, (2021)** and **Dachana *et al.*, (2010)** worked on moringa leave powder and they also observe other constituents of the leaves such as fiber, crystals of oxalate, irregular structure and particle sizes in moringa leave powder (**Reddy *et al.*, 2005**).

Rheological properties of blended dough

FWF and OLP were blended for composite flour (FWF 100%, 98% 96%, 94%, 92% and 90% and OLP incorporated with 2, 4, 6, 8 and 10% respectively. Results showed the Gluten content, and GI of FWF and composite flour as shown in Figure 2.

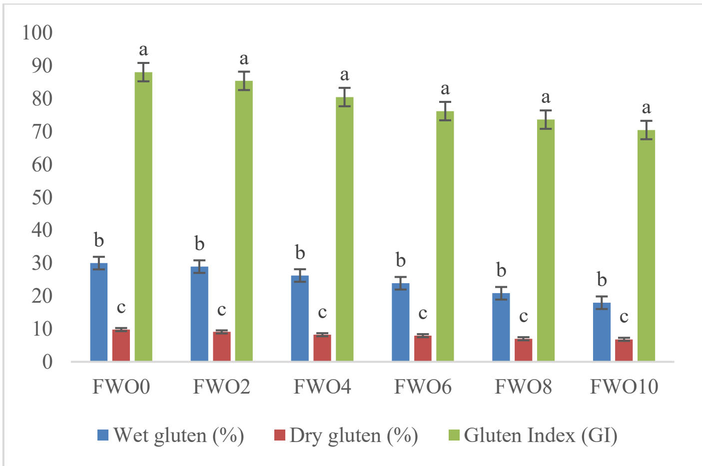


Figure 2 Gluten content of FWF and composite flour with addition of OLP,
FWO_0: 100% FWF; FWO_2: 2% OLP; FWO_4: 4% OLP; FWO_6: 6% OLP; FWO_8: 8% OLP; FWO_{10}: 10% OLP

Results showed that wet gluten, dry gluten and gluten index (GI) decreases significantly with increasing the concentration of OLP in composite flour. **Riaz *et al.*, (2021)** develop moringa leave based biscuits and also observed the decreasing trend in the gluten content of composite flour. **Hallén *et al.*, (2004)** and **Javeria *et al.*, (2023)** prepared biscuits from wheat flour with incorporation of lentil oat flour and their results showed that gluten content declined to 14.37% from 22.30% with increasing the concentration of lentil oat flour. The reason for reduction of gluten (wet, dry and GI) is because the concentration of wheat flour decreases in the recipe and olive leave powder increases as the olive leave powder lacks gluten content (**Hassanein, 2018**).

Physicochemical properties and color analysis of fortified cookie

Width of the fortified cookies declines with enhancement of olive leave powder according to the Table 2. The decline in width is due to the gluten dilution and reduction of water as the olive leaf powder contains less amount of gluten then that of wheat flour which brings a change in the dimensions of the cookie (**Nogueira and Steel, 2018**). High fiber, non-wheat flour addition reduces the width of supplemented cookies (**Sharif *et al.*, 2009**).

Results showed that thickness of fortified cookie increases with increasing the level of OLP. Declines in thickness is due to the hydrophilic nature of the non-wheat flour (Olive leave powder) with high fiber and high protein content, increase thickness of the cookies (**Rebellato *et al.*, 2015, Riaz *et al.*, 2021, Miller, 2016**).

The Spread ratio of OLP in the cookie decline significantly (P<0.05) as the level of incorporation of OLP increases. Spread ratio of cookies reduces with supplementation of non-wheat flour such as moringa leave flour, soy flour, Murrava koenigii leave powder and legume flour. As the olive leave powder has high concentration of fiber as compare to the fine wheat flour, so this fiber competes for the water with the starch within the dough and adversely affect spread ratio (**Sharif *et al.,* 2009**). The lower the spread ratio the higher the raising ability of cookie (**Cheng and Bhat 2016, Riaz *et al.,* 2021, Aljobair 2022, Dachana *et al.,* 2010, Kulthe *et al.,* 2014**) was observed. **Riaz *et al.,* (2022)** stated that during dough mixing process for cookie preparation, a competition starts among the gluten with other ingredients of the wheat flour which might be one to the reason for the decrease in the spread ratio of the final cookie (**Hooda and Jood 2005**). Higher the spread ratio the higher will be the acceptability of the cookie attributed by consumers.

Table 2 Physicochemical properties and color analysis of fortified cookie

Parameters	FOC_0	FOC_2	FOC_4	FOC_6	FOC_8	FOC_{10}
Width	55.35a± 0.04	53.64b ± 0.01	53.00c ± 0.02	52.65d ± 2.52	52.07e± 0.53	51.33f ± 1.88
Thickness	8.9f± 0.10	10.35e ± 0.14	11.07d ± 0.10	11.56c ± 0.09	12.09b± 0.02	12.87a ± 0.03
Spread Ratio	6.12a ± 0.01	5.66b± 0.21	5.66b± 0.21	4.26d ± 0.09	4.06e ± 0.06	3.80f ± 0.36
Hardness	5.75f ± 0.04	5.99e ± 0.16	6.28d ± 0.04	6.69c± 0.05	6.85b± 0.01	6.99a ± 0.03
Color analysis of fortified cookies						
L*	69.19a± 0.16	62.03b± 0.12	52.01c± 0.11	51.98d± 0.03	50.35e± 0.11	49.59f± 0.18
a*	10.51f± 0.13	11.62e± 0.12	12.96d± 0.20	13.03c± 0.16	14.52b± 0.30	15.08a± 0.03
b*	32.23a± 0.16	27.78b± 0.21	26.79c± 0.17	26.20d± 0.11	26.10e± 0.06	24.36f± 0.10

FOC0=control, FOC_2= 2% olive powder, FOC_4= 4% olive powder, FOC_6= 6% olive powder, FOC_8= 8% olive powder, and FOC_{10}=10% olive powder.

The hardness of cookies increased significantly ($p \leq 0.05$) with increasing concentration of OLP. Increase in the hardness of the cookie is due to the presence of high amount of fiber of OLP, due to which the less water is available for gluten hydration (**Sharma *et al.,* 2013, Sudha *et al.,* 2007**). Another reason for the raise in hardness of the cookies which were reported by the literature is due to raise in the protein content which might be interact with during dough development and baking (**McWatters *et al.,* 2003, Khouryieh and Aramouni 2012**). Hardness is also depended upon the water and oil absorption of flour which reinforce internal constituent of the dough which increased the hardness of the fortified cookie (**Batista *et al.,* 2017**).

Color analysis (L*, a* and b*)

L* value indicates the lightness of the cookies which was decreased with increasing concentration of OLP from 69.19 in control sample to 49.59 in FOC10 sample. Enzymatic browning and caramelization of the sugar or due to onset of Maillard reaction during the baking process at such a high temperature of 150° C browning reactions are the reasons for this decline in the value of L* (**Aljobair 2022**). Similarly, L* value decreased from 62.14 to 28.50 in the cookies supplemented with pitaya peel flour (**Ho *et al.,* 2016**).

The value of a* indicates the green and red color. The results revealed that the a* value of sample FOC_2 (11.62) increased to FOC_{10} (15.08) in fortified cookies. The color of the cookies become dark due to the incorporation of chlorophyll which impart green color to the leaves. **Chauhan *et al.,* (2016)** revealed the similar increasing trend in the value of a* for the cookies prepared by using amaranth flour, recorded the value of a* as 6.71-8.36. **Chevallier *et al.,* (2000)** indicating that the Maillard reaction played the major role in color formation.

Similarly, b* value decreased to 24.36 in sample FOC10 from FOC0 (32.23) as the concentration of OLP increases from 2, 6, 8 and 10%. Decrease in the yellowness of the cookie is might be due to degradation of unstable yellow components during baking process (**Chia *et al.,* 2015**). Similar decline in the b* value (28.08-17.83) for the cookies were also observed by **Ho *et al.,* (2016)** when substituting the wheat flour with pitaya peel flour.

Proximate composition and minerals content of fortified cookies

Proximate composition of the control sample as well as the olive leaves powder-based cookie samples were shown in Table.3. Addition of olive leave powder had a non-significant effect ($p \leq 0.05\%$) on the moisture level of fortified cookie. Results showed that moisture content in sample FOC0 was 3.79% which gradually increased to 3.92 in sample FOC4. **Jan *et al.,* (2015)** and **Faccioli *et al.,* (2021)** developed crackers with the addition of olive leaf flour and recorded a moisture level in the range of (3.71-3.87%). Moisture level of any product is important to measure its shelf life (**Bradley 2010**). The moisture content increases because the level of fiber increases as fiber have the tendency to absorb more water and tends to retain.

The ash content of the cookies increased from 1.07% in sample FOC0 to 2.21% in sample FOC10 with addition of olive leaves powder. The increase in ash content of cookie is due to higher fiber level of olive leave powder which also enhance the mineral content of the cookies (**Riaz *et al.,* 2021, Galla *et al.,* 2017**). Increase in the ash content might be due to incorporation of non-wheat flour having higher ash content which might enhances the value of ash content of cookies (**Cheng and Bhat 2016; Núñez-Gómez *et al.,* 2023; Dauda *et al.,* 2018**).

The crude fiber of the cookies increased with the incorporation of olive leaf powder. This increase in the crude fiber level is due to the enriched level of fiber in the olive leaf powder. The increase in the fiber of the cookies is might be due incorporation of olive leaf powder having higher level of crude fiber then fine wheat (**Muhammad *et al.,* 2023**). As the level of OLP increases in the cookies the fat content tends to be increased. The increase in the fat content of the cookie is due to higher level of fat in the powder of olive as compare to wheat flour for various baked goods such as cookies, biscuits, crackers and bread by incorporation of non-wheat flour (**Ikuomola *et al.,* 2017; Muhammad *et al.,* 2023; Aljobair 2022**).

Table 3 Proximate composition and mineral content of fortified cookies

Treatment	Moisture (%)	Ash (%)	Crude Fiber (%)	Crude Fat (%)	Crude Protein (%)	NFE (%)
FOC_0	3.79f± 0.11	1.07f± 0.03	1.12f± 0.03	23.05f± 0.40	7.55b± 0.10	63.42a± 0.13
FOC_2	3.85e± 0.02	1.12e± 0.04	1.55e± 0.03	23.65e± 0.79	7.75a± 0.26	62.08b± 0.02
FOC_4	3.92d± 0.11	1.35d± 0.05	2.68± 0.09	24.09d± 0.74	7.59b± 0.40	60.02c± 0.01
FOC_6	4.12c± 0.02	1.79c± 0.13	2.95c± 0.04	24.65c± 0.05	7.60b± 0.01	58.28d± 0.03
FOC_8	4.41b± 0.01	1.97b± 0.02	3.16± 0.05b	24.97b± 0.02	7.61b± 0.26	57.1e± 0.02
FOC_{10}	4.95a± 0.03	2.21a± 0.09	3.65a± 0.12	25.25a± 0.06	7.62b± 0.30	55.3f± 0.02
Mineral Content (mg/100g) of the Cookies fortified with Olive leave powder						
	Ca	**K**	**Fe**	**Zn**		
FOC_0	19.75f± 0.02	35.05f± 0.06	1.57f± 0.14	0.90f± 0.20		

FOC_2	48.20e± 0.13	38.25e± 0.23	1.92e± 0.07	1.10e± 0.05
FOC_4	55.06d± 0.04	45.72d± 0.47	2.46d± 0.02	1.58d± 0.06
FOC_6	74.15c± 0.20	48.55c± 0.02	2.97c± 0.03	2.01c± 0.09
FOC_8	85.24b± 0.10	51.51b± 1.21	3.81b± 0.18	2.53b± 0.15
FOC_{10}	105.25a± 0.04	56.17a± 0.92	4.88a± 0.04	3.74a± 0.07

FOC0=control, FOC_2= 2% olive powder, FOC_4= 4% olive powder, FOC_6= 6% olive powder, FOC_8= 8% olive powder, and FOC_{10}=10% olive powder. Values with different letters in the rows show significant difference at 5% level of significance. ± = standard deviation.

Increasing the level of OLP up to 10% enhanced the protein level of FOC_{10} (7.63%). Non-significant increase in the protein content of the cookie were also studied by using dried leaf powder of *Tinospora cordifolia,* dried spinach powder and moringa leave powder (**Galla *et al.*, 2017, Sharma *et al.*, 2013; Riaz *et al.*, 2021**). protein act as an enzyme, hormones and also it balances the electrolytes of the body by adjusting acid-base equilibrium (**Adeola and Ohizua 2018**). The value of NFE% decline with increasing concentration of OLP in the cookies, because the Olive leave powder contains lesser amount of carbohydrate then that of fine wheat flour.
Results showed that maximum reduction was observed in the sample FOC10 having 10% OLP (**Muhammad *et al.*, 2023**).

Mineral content of the fortified cookies

Mineral content of control and fortified cookies are given in Table-3 which showed that calcium content increased from 19.75 to 105.25mg 100^{-1}g with increasing the incorporation OLP in the supplemented cookie. Calcium content of cookie increased with the addition of non-wheat flour (**Galla *et al.*, 2017; Aljobair, 2022; Muhammad *et al.*, 2023**). The K content was high in sample FOC10 having 10% OLP (56.17 mg100^{-1}g) as compared to FOC0 FWF (35.05 100^{-1}g. Iron content non-significantly (P<0.05) increased from 1.57 to 4.88 mg100^{-1}g.
Fe content in supplemented cookies increased by the incorporation of clove powder in the cookie from 8.14 to 8.61 mg100^{-1} g (**Riaz *et al.*, 2022; Tessera *et al.*, 2015; Javeria *et al.*, 2023, Aljobair 2022**). The zinc content increased in the sample having 10% OLP in sample FOC10 (3.74 mg100^{-1}g) from FOC2 (1.10 mg100^{-1}g) having 2% OLP. **Riaz *et al.*, (2022)** added moringa leaves powders in various concentrations in the biscuits and observed increasing trends in Zn content (1.90 to 2.11 mg100^{-1}g). The increase in the Zn content of the cookie sample was might be due to higher level of Zn in the olive leave powder which incorporate its impact in the final product (**Tessera *et al.*, 2015**).

SEM analysis of cookies fortified with OLP

Micrograph of fortified cookies are shown in figure 3. In the control sample where no OLP is used the granules of gelatinized starch can be observed which is embedded the protein matrix. The small pores within the sample can be observed these pores are created during baking process due to expanding of gasses. The gluten observed within the image helps to maintain the dough elasticity and shape whereas the starch gives the bulk and texture to the dough (**Saifullah and Qazi, 2019**). The SEM images for other samples can be also seen in the figure, which shows that when the concentration of the olive leave powder enhances the starch protein matrix weakens as the level of fiber increases. The image, taken at x400 magnification for the FOC2 where a porous structure with air pockets throughout the structure can be observed. olive leaf powder may have slightly altered the porosity and pore distribution by changing the dough's hydration and expansion behavior. The OLP particles appear to be dispersed within the wheat flour matrix, although they may not be easily distinguishable from the flour at this magnification.
Our findings were common to the results of **Riaz *et al.*, (2021)** who used moringa leave powder in the biscuits, they also observed that protein matrix disruption of cookies occurs at the highest level of moringa leaves (10%). **Rajiv *et al.*, (2012)** also stated that when the protein is higher due to hydration the gluten network disrupted, thus starch and protein matrix dose not enwrap. Protein matrix was also disrupted while studying the SEM of multigrain dough by **Indrani *et al.*, (2010).**
The structure of the other cookie can also be observed in the Figure 2 where the structure of the cookies becomes more compact with increasing the Olive leave content from 20g to 100g. The increased level of olive leaf powder leads to a denser, more irregular structure with reduced porosity, likely affecting the cookie's texture and potentially enhancing its nutritional profile due to the added fiber and bioactive compounds. **Riaz *et al.*, (2021)** also reported these constituents in the cookies sample having moringa leave powder.
Further increasing the level up-to 6% the SEM image illustrates that a high concentration of olive leaf powder significantly changes the cookie's microstructure, leading to a denser, less porous matrix with rougher textures. This alteration in structure impacts the cookie's physical properties, making it potentially harder and more brittle while offering an enhanced nutritional profile (**Srivastava *et al.*, 2014**). Similarly, in the sample FOC8 and FOC10 having 8 and 10% OLP the images showed much compact structure of the cookies where large particles, low porous nature and other constitutes of irregular shapes were seen. Due to this level of concentration significantly disrupts the continuity of the wheat flour matrix, creating a rough, granular texture (**Riaz *et al.*, 2021**).

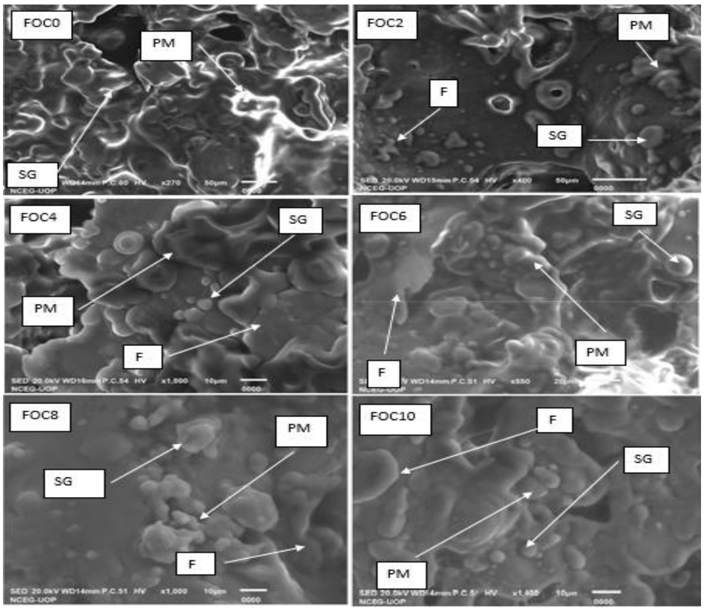


Figure 3 Micrograph (SEM) of control and fortified cookies with addition of OLP FOC0=control, FOC_2= 2% OLP, FOC_4= 4% OLP, FOC_6= 6% OLP, FOC_8= 8% OLP, FOC_{10}=10% OLP, SG: starch granule, PM: Protein matrix, F, Fiber.

Sensory evaluation of fortified cookies

Color is the sensory property which enhances the esthetic sense of any product and also exerts its effect on the taste and flavor. The addition of OLP from FOC2 (7.90) to FOC10 (5.25) in the cookies significantly affect the color of the cookies as shown in Figure 4. **Riaz *et al.*, (2022)** also observed reduction in the color score from 7.86 to 5.71 by using moringa leave powder. Increasing level of OLP from 6% to 10% has a negative effect on taste of the cookie FOC6 (7.83) to FOC10 (5.03). **Riaz *et al.*, (2022)** also observed decrease in the taste of biscuits (7.73 to 6.36) by enhancing the level of moringa leave powder. While **Sedej *et al.*, (2011)** reported that taste of the cookies is might be affected due to the phelolic compounds in the olive leaves powder. Increasing the level of OLP from FOC2 (2%) to FOC10(10%) in the cookies the texture significant decreased from 7.81 to 5.79 (**Faccioli *et al.*, 2021**). Overall acceptability of cookies showed that increasing the level of OLP from 6% to 10%. The reason for this decline in the acceptability was given by (**Ikuomola *et al.*, 2017**) is his study on cookies and stated that bitter after taste, darkish brown color, herbaceous aroma and brittle texture decrease the overall likeness of the final product (**Muhammad *et al.*, 2023**).

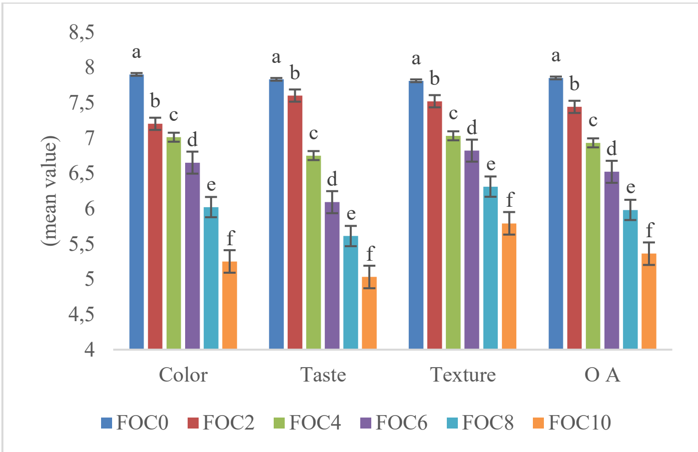


Figure 4 Sensory Evaluation of Cookies fortified with olive leaves powder
FOC0=control, FOC_2= 2% OLP, FOC_4= 4% OLP, FOC_6= 6% OLP, FOC_8= 8% OLP, FOC_{10}=10% OLP, OA= overall acceptability

CONCLUSION

Fortified cookies were developed with the incorporation of olive leaf powder (OLP) at varying concentrations (0, 20, 40, 60, 80, and 100 g/kg flour). In composite flours, increasing OLP levels significantly reduced wet (30.02% to 17.97%) and dry gluten (9.10% to 6.84%), with SEM micrographs indicating compact structures due to fiber content in olive leaves powder. In cookies, higher OLP levels reduced width and spread ratio due to high fiber content which absorb moisture content but increased other parameters such as thickness, hardness, and levels of moisture, ash, fiber, fat, protein, and minerals, while NFE decreased. Results indicate that cookies with 4% OLP were highly acceptable followed by 6% OLP, offering enhanced nutritional benefits and prolonged shelf life. Fortified cookies sample FOC4 (4%) was found best on the basis of sensory evaluation by the panel of judges followed by sample FOC6 (6% of OLP). Industrial application of OLP in preparation of cookies will not only enhance the minerals contents, fiber and bioactive compounds in food supplements but it will also help to reduce environmental pollution by utilization of olive leaves which generate a huge waste during cutting and pruning of olive trees.

Acknowledgments: The authors acknowledged, The University of Agriculture Peshawar.

REFERENCES

AACC, (2010). Approved methods of American Association of Cereal Chemists. American Association of Cereal Chemists, St. Paul, MN.
Adeleke, R.O. & Odedeji, J.O. (2010). Functional Properties of Wheat and Sweet Potato Flour Blends. *Pakistan Journal of Nutrition, 9*(6), 535-538. https://doi.org/10.3923/pjn.2010.535.538
Adeola, A.A. & Ohizua, E.R. (2018). Physical, chemical, and sensory properties of biscuits prepared from flour blends of unripe cooking banana, pigeon pea, and sweet potato. *Food Science and Nutrition, 6* (3), 532-540. https://doi.org/10.1002/fsn3.590
Aliyari, M.A., Salami, M., Hosseini, E., Zahra, E.D., Karboune, S. & Waglay, A. (2021). Biophysical, Rheological, and Functional Properties of Complex of Sodium Caseinate and Olive Leaf Aqueous Polyphenolic Extract Obtained Using Ultrasound-Assisted Extraction. *Food Biophysics, 16*(3), 325-336. https://doi.org/10.1007/s11483-021-09671-1
Aljobair, M.O. (2022). Physicochemical, Nutritional, and Sensory Quality and Storage Stability of Cookies-Effect of Clove Powder. *International Journal of Food Properties, 25*(1), 1009-1020. https://doi.org/10.1080/10942912.2022.2071290
Anjali, P., Lal, E.A., Ajinkaya, D. (2019). Value addition and quality evaluation of dietary fibre rich, multigrain cookies. *Journal of Pharmacognosy and Phytochemistry 8*(1), 1802-1804.
Appiah, F., Asibuo, J.Y. & Kumah, P. (2011). Physicochemical and Functional Properties of Bean Flours of Three Cowpea (Vigna unguiculata L. Walp) Varieties in Ghana. *African Journal of Food Science, 5,* 100-104. https://doi.org/10.17660/ActaHortic.2011.911.51
Asmaey, M.A., Elsoghiar, A.A.M., Shaaban, M., Moharram, A.M. & El-Gaby, M.S.A. 2024. Phenolics and Other Structural Compounds from Leaves of Olea europaea L.: Extraction Techniques and Pharmacological Activities. *Chemistry Africa*. https://doi.org/10.1007/s42250-024-01110-1
Barazani, O., Dag, A., Dunseth, Z. (2023). The history of olive cultivation in the southern Levant. *Frontiers in Plant Science,* 23;14, 1131557. https://doi.org/10.3389/fpls.2023.1131557
Batista, A.P., Niccolai, A., Fradinho, P., Fragoso, S., Bursic, I., Rodolfi, L., Biondi, N., Tredici, M.R., Sousa, I. & Raymundo, A. (2017). Microalgae biomass as an alternative ingredient in cookies: Sensory, physical and chemical properties, antioxidant activity and in vitro digestibility. *Algal Research, 26,* 161-171. https://doi.org/10.1016/j.algal.2017.07.017
Bradley, R.L. 2010. Moisture and Total Solids Analysis. Food Analysis. 85-104. https://doi.org/10.1007/978-1-4419-1478-1_6
Burchi, F., Fanzo, J. & Frison, E. (2011). The role of food and nutrition system approaches in tackling hidden hunger. *International Journal of Environmental Public Health 8*(2), 358-73. https://doi.org/10.3390/ijerph8020358
Cayan, H. & Erener, G. (2015). Effect of Olive Leaf (*Olea europaea*) Powder on Laying Hens Performance, Egg Quality and Egg Yolk Cholesterol Levels. Asian-Australasian Journal of Animal Sciences. *Asian Australasian Association of Animal Production Societies* pp. 538–543. https://doi.org/10.5713/ajas.14.0369
Chandra, S., Singh, S. & Kumari, D. (2014). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of Food Science and Technology, 52*(6), 3681-8. doi: 10.1007/s13197-014-1427-2
Chauhan, A., Saxena, D.C. & Singh, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. *Cogent food & Agriculture, 2*: 1125773. https://doi.org/10.1080/23311932.2015.1125773
Cheng, Y.F. & Bhat, R. (2016). Functional, physicochemical and sensory properties of novel cookies produced by utilized jering (Pithecellobium jiringa Jack.) legume flour. *Food Bioscience, 14*, 54-61. https://doi.org/10.1016/j.fbio.2016.03.002
Chevallier, S., Colonna, P. & Valle, G.D. (2000). Contribution of Major Ingredients during Baking of Biscuit Dough Systems. *Journal of Cereal Science, 31*(3), 241-252. https://doi.org/10.1006/jcrs.2000.0308
Chia, S.L. & Chong, G.H. (2015). Effect of Drum Drying on Physico-chemical Characteristics of Dragon Fruit Peel (*Hylocereus polyrhizus*). *International Journal of Food Engineering, 11*, 285-293. https://doi.org/10.1515/ijfe-2014-0198
Dachana, K., Rajiv, J., Indrani, D. & Prakash, J. (2010). Effect of dried moringa (moringa oleifera lam) leaves on rheological, microstructural, nutritional, textural and organoleptic characteristics of cookies. *Journal of Food Quality, 33*(5), 660-677. https://doi.org/10.1111/j.1745-4557.2010.00346
Dauda, A.O., Abiodun, O.A., Arise, A.K. & Oyeyinka, S.A. (2018). Acceptance of biscuit made from wheat flour fortified with partially defatted groundnut paste. *LWT Food Science and Technology, 90*, 265-269. https://doi.org/10.1016/j.lwt.2017.12.039
De Oliveira, N.M., Lopes, L., Chéu, M.H., Soares, E., Meireles, D. & Machado, J. (2023). Updated Mineral Composition and Potential Therapeutic Properties of Different Varieties of Olive Leaves from Olea Europaea. *Plants, 12*, 916. https://doi.org/10.3390/plants12040916
Difonzo, G., Squeo, G., Calasso, M., Pasqualone, A. & Caponio, F. (2019). Physico-Chemical, Microbiological and Sensory Evaluation of Ready-to-Use Vegetable Pâté Added with Olive Leaf Extract. *Foods, 8*(4), 138. https://doi.org/10.3390/foods8040138
Ewulo, T., Oluwalana, I., Ewulo, B., Awolu, O. (2017). Enrichment of traditional maize snack (Kokoro) with moringa (Moringa oliefera) leaf and soybean. *African Journal of Food Science, 11*(5), 140-145. https://doi.org/10.5897/AJFS2017.1490
Faccioli, L.S., Klein, M.P., Borges, G.R., Dalanhol, C.S., Machado, I.C.K., Garavaglia, J. & Bosco, S.M.D. (2021). Development of crackers with the addition of olive leaf flour (Olea europaea L.): Chemical and sensory characterization. *LWT Food Science and Technology, 141*, 110848. https://doi.org/10.1016/j.lwt.2021.110848
Galla, N.R., Pamidighantam, P.R. & Karakala, B., Gurusiddaiah, M.R., Akula, S. (2017). Nutritional, textural and sensory quality of biscuits supplemented with spinach (*Spinacia oleracea L.*). *International Journal of Gastronomy and Food Science, 7*, 20-26. https://doi.org/10.1016/j.ijgfs.2016.12.003
Godswill, A. C. 2019. Proximate composition and functional properties of different grain flour composites for industrial applications. *International Journal of Food Sciences 2*(1), 43-64. https://doi.org/10.47604/ijf.1010
Gullón, P., Gullón, B., Astray, G., Carpena, M., Fraga-Corral, M. & Prieto, M.A. (2020). Simal-Gandara J. Valorization of by-products from olive oil industry and added-value applications for innovative functional foods. *Food Research International, 137*, 109683.
Gutierrez, A.D.R., Guilbert, S. & Cuq, B. (2002). Description of Microstructural Changes in Wheat Flour and Flour Components during Hydration by using Environmental Scanning Electron Microscopy, *LWT, 35*(8), 730-740. https://doi.org/10.1006/fstl.2002.0932
Hallén, E., İbanoğlu, S. & Ainsworth, P. 2004. Effect of Fermented/Germinated Cowpea Flour Addition on the Rheological and Baking Properties of Wheat Flour. *Journal of Food Engineering, 63*(2), 177-184. https://doi.org/10.1016/S0260-8774(03)00298-X
Hassanein, A.M.A. (2018). Nutritional, chemical and molecular characterisation of Moringa oleifera Lam. and Moringa peregrina (Forssk.) Fiori genotypes. *The Journal of Horticultural Science and Biotechnology, 93*(5), 500-509. https://doi.org/10.1080/14620316.2017.1399834
Ho, L.H. & Latif, N.W.B.A. (2016). Nutritional composition, physical properties, and sensory evaluation of cookies prepared from wheat flour and pitaya (*Hylocereus undatus*) peel flour blends. *Cogent Food & Agriculture, 2,* 1136369. https://doi.org/10.1080/23311932.2015.1136369
Hooda, D.S. & Jood, S. (2005). Organoleptic and Nutritional Evaluation of Wheat Biscuits Supplemented with Untreated and Treated Fenugreek Flour. *Food Chemistry, 90*(3), 427-435. https://doi.org/10.1016/j.foodchem.2004.05.006
Ikuomola, D., Otutu, O. & Oluniran, D. (2017). Quality assessment of cookies produced from wheat flour and malted barley (Hordeum vulgare) bran blends. *Cogent Food & Agriculture,* 3, 1293471. https://doi.org/10.1080/23311932.2017.1293471
Indrani, D., Soumya, C., Rajiv, J. & Rao, G.V. (2010). Multigrain bread – its dough rheology, microstructure, quality and nutritional characteristics. *Journal of Texture Studies 41*(3), 302-319. https://doi.org/10.1111/j.1745-4603.2010.00230.x
Jan, U., Gani, A., Ahmad, M. & Shah, U., Baba, W.N., Masoodi, F.A., Maqsood, S., Gani, A., Wani, I.A., Wani, S.M. (2015). Characterization of cookies made from wheat flour blended with buckwheat flour and effect on antioxidant properties. *Journal of Food Science and Technology 52*(10), 6334-6344. DOI: https://doi.org/10.1007/s13197-015-1773-8
Janati, S.S.F., Beheshti, H.R., Feizy, J. & Fahim, N.K. (2012). Chemical composition of lemon (Citrus limon) and peels its considerations as animal food. *Gida, 37*, 267–71. Google Scholar
Javeria, S., Khan, A., Riaz, A., Nadee, M., Abid, M., Sadiq, S. & Hashim, M.M. (2023). Enhancement of Nutritional Profile, Rheological and Quality Features of Wheat Flour Biscuits Supplemented with Lentil-oat Flour. *Pakistan Journal of Scientific and Industrial Research Series B: Biological Sciences, 66B*(2), 138-145. https://v2.pjsir.org/index.php/biological-sciences/article/view/3020

Kaur, G., Sharma, S., Nagi, H.P. & Dar, B.N. (2012). Functional properties of pasta enriched with variable cereal brans. *Journal of Food Science and Technology, 49*(4), 467-74. doi: https://doi.org/10.1007/s13197-011-0294-3

Khouryieh, H. & Aramouni, F. (2012). Physical and sensory characteristics of cookies prepared with flaxseed flour. *Journal of the Science of Food Agriculture, 92*(11), 2366-2372. https://doi.org/10.1002/jsfa.5642

Kinsella, J.E. (1979). Functional properties of soy proteins. *Journal of the American Oil Chemist's Society, 56*(3), 242–259. https://doi.org/10.1007/BF02671468

Kulthe, A.A., Pawar, V.D., Kotecha, P.M., Chavan, U.D. & Bansode, V.V. (2014). Development of high protein and low calorie cookies. *Journal of Food Science and Technology, 51* (1), 153-157. DOI: 10.1007/s13197-011-0465-2

Kumar, P., Yadava, R.K., Gollen, B., Kumar, S., Verma, R.K. & Yadav, S. (2011). Nutritional Contents and Medicinal Properties of Wheat: A Review. *Life Sciences and Medicine Research, 22*, 1-7. Google Scholar

Lalas, S., Athanasiadis, V., Karageorgou, I., Batra, G., Nanos, G.D. & Makris, D.P. (2017). Nutritional characterization of leaves and herbal tea of Moringa oleifera cultivated in Greece. *Journal of Herbs, Spices & Medicinal Plants, 24*, 320-333. https://doi.org/10.1080/10496475.2017.1334163

Larmond, E. 1997. Laboratory Methods for Sensory Evaluation of Foods. Canada Department of Agriculture Publication, Ottawa, Inter science Publishing, New York.

Liu, S., Alavi, S. & Abughoush, M. (2011). Extruded Moringa Leaf–Oat Flour Snacks: Physical, Nutritional, and Sensory Properties. *International Journal of Food Properties, 14* (4), 854-869. https://doi.org/10.1080/10942910903456358

Manley, D. 2011. 10-Meals, grits, flours and starches (other than wheat), Editor(s): Duncan Manley, In Woodhead Publishing Series in Food Science, Technology and Nutrition, Manley's Technology of Biscuits, Crackers and Cookies (Fourth Edition), Woodhead Publishing 2011, 134-142. https://doi.org/10.1533/9780857093646.2.134

McWatters, K.H., Ouedraogo, J.B., Resurreccion, A.V., Hung, Y.C. & Phillips, R.D. (2003). Physical and sensory characteristics of sugar cookies containing mixtures of wheat, fonio (Digitaria exilis) and cowpea (Vigna unguiculata) flours. *International Journal of Food Science and Technology, 38* (4), 403-410. https://doi.org/10.1046/j.1365-2621.2003.00716.x

Miller, R. (2016). Biscuits, cookies and crackers: Nature of the products. *Encyclopedia of Food and Health*, 445-450, https://doi.org/10.1016/B978-0-12-384947-2.00075-1

Muhammad, A., Dayisoylu, K.S., Pei, J., Khan, M.R., Salman, M., Ahmad, R., Ullah, H. & Noor, G.R. (2023). Compositional analysis of natural pomegranate peel powder dried by different methods and nutritional and sensory evaluation of cookies fortified with pomegranate peel powder. *Frontiers in Nutrition, 14*;10, 1118156. https://doi.org/10.3389/fnut.2023.1118156

Narayana, K. & Narasinga, R.M.S. (1982). Functional properties of raw and heat processed winged bean flour. *Journal of Food Science, 42*, 534-538. https://doi.org/10.1111/j.1365-2621.1982.tb04976.x

Nogueira, A.D.C. & Steel, C.J. (2018). Protein enrichment of biscuits: A review. *Food Reviews International, 34*(8), 796–809. https://doi.org/10.1080/87559129.2018.1441299

Núñez-Gómez, V., González-Barrio, R. & Periago, M.J. (2023). Interaction between Dietary Fibre and Bioactive Compounds in Plant By-Products: Impact on Bioaccessibility and Bioavailability. *Antioxidants (Basel), 12*(4), 976. https://doi.org/10.3390/antiox12040976

Parda, J. & Aguilera, J.M. (2011). Microstructure, mechanical properties, and starch digestibility of cooked dough made with potato starch and wheat gluten. *LWT-Food Science and Technology, 44*, 1739-1744. https://doi.org/10.1016/j.lwt.2011.03.012

Qazi, I.M., Rakshit, S.K., Tran, T. 2014. Effect of blending selected tropical starches with rice flour on the cooking quality and texture of rice based noodles. *Sarhad Journal of Agriculture, 30*(2), 257-264.

Rahmanian, N., Jafari, S.M. & Wani, T.A. (2015). Bioactive profile, dehydration, extraction and application of the bioactive components of olive leaves, *Trends in Food Science & Technology, 42*(2), 150-172. https://doi.org/10.1016/j.tifs.2014.12.009

Rajiv, J., Lobo, S., Lakshmi, A.J. & Rao, G.V. (2012). Influence of green gram flour (phaseolus aureus) on the rheology, microstructure and quality of cookies. *Journal of Texture Studies, 43*(5), 350-360. https://doi.org/10.1111/j.1745-4603.2012.00346.x

Rasper, V., Rasper, J. & Mabey, G.L. (1974). Functional Properties of Non-Wheat Flour Substitutes in Composite Flours. I. The Effect of Non-Wheat Starches in Composite Doughs. *Canadian Institute of Food Science and Technology Journal, 7*(2), 86-97. https://doi.org/10.1016/S0315-5463(74)73869-X

Rebellato, A.P., Pacheco, B.C., Prado, J.P. & Pallone, J.A.L. (2015). Iron in fortified biscuits: A simple method for its quantification, bioaccessibility study and physicochemical quality. *Food Research International, 77*, 385-391. https://doi.org/10.1016/j.foodres.2015.09.028

Reddy, V., Urooj, A. & Kumar, A. (2005). Evaluation of antioxidant activity of some plant extracts and their application in biscuits, *Food Chemistry, 90*(1-2), 317-321. https://doi.org/10.1016/j.foodchem.2004.05.038

Riaz, A., Wahab, S. (2021). Efficacy of Moringa Leaves Powder as a Supplement in Whole Wheat Flour Biscuit. *Sarhad Journal of Agriculture, 37*(2), 573-585. https://dx.doi.org/10.17582/journal.sja/2021/37.2.573.585

Riaz, A., Wahab, S., Ayub, M., Hashmi, M.S. & Jabeen, F. (2022). Food to food fortification of whole wheat flour biscuit using moringa leaves powder. *Emirates Journal of Food and Agriculture 34*(2), 128-134. https://doi.org/10.9755/ejfa.2022.v34.i2.2816

Saifullah & Qazi, I.M. (2019). Comparative study of fine and whole wheat flour of selected varieties grown in Khyber Pakhtunkhwa. *Sarhad Journal of Agriculture, 35*(4), 1272-1283. http://dx.doi.org/10.17582/journal.sja/2019/35.4.1272.1283

Sedej, I., Sakak, M., Mandic, A., Misan, A. & Tumbas, V. (2011). Assessment of antioxidant activity and rheological properties of wheat and buckwheat milling fractions. *Journal of Cereal Science, 54*, 347-353. https://doi.org/10.1016/j.jcs.2011.07.001

Selim, S., Albqmi, M., Al-Sanea, M.M., Alnusaire, T.S., Almuhayawi, M.S., AbdElgawad, H., Al Jaouni, S.K., Elkelish, A., Hussein, S., Warrad, M. & El-Saadony, M.T. (2022). Valorizing the usage of olive leaves, bioactive compounds, biological activities, and food applications: A comprehensive review. *Frontier in Nutrition, 8*;9, 1008349. https://doi.org/10.3389/fnut.2022.1008349

Sharif, M.K., Butt, M.S., Anjum, F.M. & Nawaz, H. (2009). Preparation of Fiber and Mineral Enriched Defatted Rice Bran Supplemented Cookies. *Pakistan Journal of Nutrition, 8* (5), 571-577. DOI: 10.3923/pjn.2009.571.577

Sharma, P., Velu, V., Indrani, D. & Singh, R. (2013). Effect of dried guduchi (Tinospora cordifolia) leaf powder on rheological, organoleptic and nutritional characteristics of cookies. *Food Research International, 50*(2), 704-709. https://doi.org/10.1016/j.foodres.2012.03.002

Shokery, E., El-Ziney, M., Yossef, A. & Mashaly, R. (2017). Effect of Green Tea and Moringa Leave Extracts Fortification on the Physicochemical, Rheological, Sensory and Antioxidant Properties of Set-Type Yoghurt. *Advances in Dairy Research, 5*, 2. https://doi.org/10.4172/2329-888X.1000179

Singh, A., Hung, Y., Corredig, M., Phillips, D.R., Chinnan, S.M. & McWatters, H.K. (2005). Effect of milling method on selected physical and functional properties of cowpea (Vigna unguiculata) paste. *International Journal of Food Science and Technology, 40*(5), 525-536. https://doi.org/10.1111/j.1365-2621.2005.00964.x

Srivastava, P., Indrani, D. & Singh, R. (2014). Effect of dried pomegranate (*Punica granatum*) peel powder (DPPP) on textural, organoleptic and nutritional characteristics of biscuits. *International Journal of Food Science and Nutrition, 65*(7), 827-833. https://doi.org/10.3109/09637486.2014.937797

Steel, R.G.D., Torrie, J.H. & Dicky, D.A. (1997). Principles and Procedures of Statistics, A Biometrical Approach. 3rd Edition, McGraw Hill, Inc. Book Co., New York, 352-358.

Sudha, M., Vetrimani, R. & Leelavathi, K. (2007). Influence of fibre from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality. *Food Chemistry, 100* (4), 1365-1370. https://doi.org/10.1016/j.foodchem.2005.12.013.

Sui, Z., Locus, P.W. & Corke, H. (2006). Optimal cooking time of noodles related to their notch sensitivity. *Journal of Texture Studies, 37*(4), 428–441. https://doi.org/10.1111/j.1745-4603.2006.00061.x

Tessera, G.M., Haile, A. & Kinfe, E. (2015). Bioavailability of Minerals in Cookies Developed from Blend of Moringa Leaf Powder and Wheat Flour for Iron Deficient Lactating Mothers. *International Journal of Food Science and Nutrition Engineering, 5*(6), 226-232. https://doi.org/10.5923/j.food.20150506.02

Uvere, P.O., Onyekwere, E.U. & Ngoddy, P.O. (2010). Production of maize-bambara groundnut complementary foods fortified pre-fermentation with processed foods rich in calcium, iron, zinc and provitamin A. *Journal of the Science of Food and Agriculture 90*(4), 566-73. https://doi.org/10.1002/jsfa.3846