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Determination of the physical quality, structural characteristics, and sensory acceptability of biscuits prepared from einkorn-based lentil composite flours

Siyez bazlı mercimek kompozit unlarından hazırlanan bisküvilerin fiziksel kalitesi, yapısal özellikleri ve duyusal kabul edilebilirliğinin belirlenmesi

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ABSTRACT

Composite flour refers to a blend of flours sourced from tubers, grains, legumes, oilseeds, vegetables, and fruits, utilized in the formulation of bakery, pastry, and complementary food products in addressing protein-energy malnutrition and micronutrient deficiencies, the inclusion of high-protein legume is essential. Hence, the objective of this research was to produce biscuits with enhanced physicochemical attributes and sensory properties using composite flours prepared with einkorn flour-based green, red, and yellow lentil flours. According to the obtained results, all lentil flours except red lentil flour significantly increased the WAC (water absorption capacity) value of einkorn flour-based composite flours ($p < 0.05$). Specifically, composite flour containing red lentil flour exhibited the highest foam capacity at 16.00%, followed by samples formulated with yellow (S2) and green lentil flour (S1), and control (C) samples, respectively. The differences in composite flour formulations had a significant effect ($p < 0.05$) on the specific volume and spread ratio of biscuits. Specific volume measurements for control biscuits (1.70 cm^3 g^{-1}) were notably higher compared to the lower values recorded for composite biscuits (0.92–1.24 cm^3 g^{-1}). According to scanning electron microscope (SEM) results, the control biscuit exhibited a noticeably crumbly texture, unlike the other samples, which had a more cohesive starch-gluten composite network. Panelists showed a preference against biscuits containing all lentil flours together (S4), as evidenced by lower scores in terms of color, odor, brittleness, and taste. Additionally, the results underscored the significance of the formulated products in enhancing dietary variety and addressing food fortification within low-income households.

Key Words: Composite flour, einkorn, biscuit SEM microscopy, biscuit sensory attributes

ÖZ

Kompozit un, fırıncılık, pastacılık ve tamamlayıcı gıda ürünlerinin formülasyonunda kullanılan yumru kökler, tahıllar, baklagiller, yağlı tohumlar, sebzeler ve meyvelerden elde edilen unların bir karışımını ifade eder. Yüksek protein içeriğine sahip baklagillerin kullanımı, protein-enerji yetersizliği ve mikrobesin eksikliklerinin iyileştirilmesinde hayati bir rol oynamaktadır. Bu nedenle, bu çalışmanın amacı, siyez unu bazlı yeşil, kırmızı ve sarımercimek unları ile hazırlanan kompozit unlarla daha iyi fizikokimyasal özelliklere ve duyusal kabul edilebilirliğe sahip bisküviler geliştirmektir. Elde edilen sonuçlara göre, kırmızı mercimek unu hariç tüm mercimek unları, siyez unu bazlı kompozit unların WAC (su emme kapasitesi) değerini önemli ölçüde artırdığı gözlenmiştir ($p < 0.05$). Özellikle, en yüksek köpük kapasitesi %16.00 ile kırmızı mercimek unu içeren kompozit unda kaydedilmiş ve onu sırasıyla sarımercimek unu (S2) ve yeşil mercimek unu (S1) ile hazırlanan unlar ile kontrol (C) örnekleri izlemiştir. Kompozit un formülasyonlarındaki farklılıklar bisküvilerin yayılma oranı ve özgül hacim değerlerini önemli ($p < 0.05$) ölçüde etkilemiştir. Kontrol bisküvileri için özgül hacim ölçümleri (1.70 $cm^3 g^{-1}$), kompozit bisküviler için kaydedilen daha düşük değerlerle (0.92–1.24 $cm^3 g^{-1}$) karşılaştırıldığında belirgin şekilde daha yüksek bulunmuştur. SEM analiz sonuçları, kontrol bisküvisinin, diğer numunelerde gözlemlenen daha bütünleşik nişasta-gluten ağına kıyasla, belirgin bir kırılgan dokuya sahip olduğunu ortaya koymaktadır. Panelistler, renk, koku, kırılganlık ve tat açısından daha düşük puanlarla ifade edilen, tüm mercimek unlarını içeren (S4) bisküvileri daha az tercih etmiştir. Çalışmanın bulguları, geliştirilen ürünlerin düşük gelirli ailelerin beslenme çeşitliliğini artırmada ve gıdaların besin değerini zenginleştirmede önemli bir katkı sağladığını ortaya koymuştur.

Anahtar Kelimeler: Kompozit un, siyez unu, bisküvi SEM mikroskobu, bisküvi duyusal özellikleri

Introduction

The bakery industry, especially the segment dedicated to biscuits, offers a wide variety of products that are popular due to their convenient consumption and economical value (Arepally, Reddy, Goswami, & Datta, 2020; Misra & Tiwari, 2014). Traditionally, biscuits are made from a basic combination of flour, eggs, butter, and sugar. However, with the increasing health awareness among consumers, there has been a significant shift towards developing innovative food products that offer specific health benefits (Lippolis, Cofano, Caponio, De Nunzio, & Notarnicola, 2023). This trend has opened up opportunities for reformulating biscuits to improve their nutritional profile. One promising approach is the use of composite flours, which are blends of flours from various sources such as tubers, grains, legumes, oilseeds, vegetables, and fruits. Composite flours not only reduce dependency on wheat imports but also promote the use of domestic and underutilized crops while enhancing the nutritional value of food products (Akinola, Pereira, Mabhaudhi, De Bruin, & Rusch, 2020; Hasmadi, Noorfarahzilah, Noraidah, Zainol, & Jahurul, 2020). While the baking industry has traditionally relied on wheat flour for its gluten content, which provides key properties like plasticity, elasticity, and viscosity, its nutritional profile is often lower in minerals and protein compared to legumes (Dewettinck et al., 2008). Therefore, the incorporation of composite flours, rich in protein and fiber, is being advocated by food scientists to improve the nutritional composition of biscuits, reduce production costs, and decrease waste (Ezegbe, Onyeka, & Nkhata, 2023). Consequently, there has been a growing interest in producing biscuits by blending wheat with various non-wheat ingredients, such as common bean and defatted soybean (de Oliveira Silva et al., 2018), groundnut (Dauda, Abiodun, Arise, & Oyeyinka, 2018), chickpea (Lu, He, Liu, Wen, & Xia, 2022), and fluted pumpkin (Melese & Keyata, 2022).

Biscuits commonly found in the market are typically prepared from wheat flour, which often lacks sufficient quality protein due to its limited lysine content, as well as dietary fiber (Chandra, Singh, & Kumari, 2015a). This research utilized lentil (yellow, red, green) flour and einkorn flour, renowned for their exceptional nutritional profiles rich in protein, vitamins, and minerals, in biscuit formulation (Brandolini & Hidalgo, 2011; Romano, Gallo, Ferranti, & Masi, 2021). While the concept of employing composite flour in the baking industry is not novel (Aljahani, 2022; Dahal, Dangal, Pradhananga, Timsina, & Timsina, 2022; Ginindza, Solomon, Shelembe, & Nkambule, 2022; Jukić et al., 2022), extensive data on biscuits produced from blends of einkorn flour and lentil flour are scarce. Existing literature indicates that einkorn flour boasts superior carbohydrate and starch content (Brandolini & Hidalgo, 2011), while lentil flour is distinguished for its high protein content (Romano et al., 2021). The study presents insights into a commercially viable approach aimed at augmenting the protein and fiber content of biscuits (Cankurtaran-Kömürcü & Bilgiçli, 2023; Chelladurai & Erkinbaev, 2020; Goencue & Çelik, 2020), thereby addressing societal challenges associated with malnutrition and deficiencies in essential macro- and micronutrients. Lentil varieties exhibit a spectrum of colors, including yellow, green, red, brown, and black. Notably, red lentils account for about 80% of global lentil consumption (Asif, Rooney, Ali, & Riaz, 2013). In this study, we focused on red, green, and yellow lentils due to their significant role in pulse production, processing, and marketing in Türkiye. Furthermore, the study sought to enhance the utilization of lentil and einkorn flour by integrating them with wheat flour, forming composite flour, to enhance the quality and characterization of biscuits. This study was conducted to assess the techno-functional attributes of composite flours, as well as to evaluate consumer acceptance of the biscuits produced from these flours.

Materials and Methods

Materials and chemicals

The einkorn flour (63.1% carbohydrate, 2.4% fat, 10.2% dietary fiber, 10.8% protein) used in the preparation of composite flours, along with green lentil (63.62% carbohydrate, 0.92% fat, 8.8% dietary fiber, 23.00% protein), yellow lentil (59.5% carbohydrate, 1.5% fat, 25.99% dietary fiber, 24.94% protein), and red lentil (63.0% carbohydrate, 1.0 fat%, 8.8% dietary fiber, 25.0% protein) flours were purchased from local markets. Butter, salt, sugar, milk, eggs, and vanilla used for biscuit preparation were sourced from local markets located in Kayseri, Türkiye.

Methods

Preparation of composite flour

To produce composite flour, einkorn flour and lentil flours (yellow, red, green) were mixed in different proportions. The mixing ratios of the composite flours used in the study are given in Table 1.

Table 1. The blending ratio of the flours

Samples	EF (%)	GLF (%)	YLF (%)	RLF (%)
C	100	-	-	-
S1	50	50	-	-
S2	50	-	50	-
S3	50	-	-	50
S4	50	16.66	16.66	16.66

C: Control, EF: einkorn flour, GLF: green lentil flour, YLF: yellow lentil flour, RLF: red lentil flour

Techno-functional properties of composite flours

Loose/Tapped Bulk Density and Hausner ratio

Bulk density indicates the mass or weight contained in a unit volume of particulate matter (Oshins, Michel, Louis, Richard, & Rynk, 2022). To conduct loose bulk density analysis, composite flours were carefully poured into 50 mL measuring cylinders without any compression, and their respective weights were recorded. Loose bulk density analyzes were determined by mass/volume ratio calculation (Du, Jiang, Yu, & Jane, 2014b). Tapped bulk density of composite flours was determined according to the method described by Gupta, Parvez, and Sharma (2015). The Hausner ratio (HR) is used to assess flowability, reflecting the resistance encountered in a bed of particles as a result of their interparticle interactions (Gaikwad et al., 2023). The Hausner ratio of the samples was assessed following the method outlined by Mahesh (2018).

Water Absorption Capacity (WAC)

The WAC of the composite flours was assessed using the procedure outlined by Adebowale, Adegoke, Sanni, Adegunwa, and Fetuga (2012). The sample, weighing one gram, was combined with 10 mL of distilled water at room temperature and mixed for 30 seconds. The suspension was left undisturbed for 30 minutes prior to centrifugation. After centrifugation, the centrifuge tube was kept open, and the supernatant was carefully drained.

The tube was reweighed, and the variance between the initial and final weights after draining the supernatant yielded the WAC, expressed as grams of water retained per gram of flour sample.

Oil Absorption Capacity (OAC)

About one gram of the sample was measured into pre-weighed 15 ml centrifuge tubes and mixed extensively with 10 ml of refined corn oil using a vortex mixer. Following mixing, the samples were left to stand for 30 minutes. The centrifuged sample-oil mixture was carefully decanted into a graduated cylinder immediately after centrifugation, and the volume was noted. Subsequently, the oil absorption capacity was computed (Achy, Ekissi, Kouadio, Koné, & Kouamé, 2017).

Swelling Power

One gram of flour sample was precisely weighed and placed into a clean, dry test tube, which was then reweighed for accuracy. About 15 mL of distilled water was added, followed by gentle stirring for 5 minutes at low speed. The suspension underwent heating at 75°C in a thermostatically controlled water bath for 30 minutes, with intermittent stirring to avoid lump formation. The test tube and its contents were quickly cooled to 20°C. Subsequently, the cooled paste underwent centrifugation, and immediately after, the supernatant was transferred into a pre-weighed evaporation dish. The supernatant was then dried at 100°C for approximately 4 hours until a constant weight was achieved. The weight of the residue was measured and reported as the mass after swelling (Tangsrianugul, Wongsagonsup, & Suphantharika, 2019).

Foaming Capacity

The foaming capacity of the samples was assessed following the procedure outlined by Chandra, Singh, and Kumari (2015b). The sample (1 gram) was introduced into 50 ml of distilled water at 30 ± 2 °C within a 100 mL graduated cylinder. Subsequently, the mixture was vigorously stirred and agitated for 5 minutes to induce foam formation. Following 30 seconds of agitation, the foam volume was quantified as the foaming capacity.

Dispersibility

Ten grams of flour sample were measured into a 100 ml measuring cylinder, and water was added until reaching a total volume of 100 ml. The mixture was then vigorously stirred and left to stand for 3 hours. The volume of settled particles was measured, and dispersibility was calculated as the percentage remaining after subtracting it from 100 (AACC, 2000).

Preparation of biscuits

To obtain a doughy consistency, composite flours (200 g) as illustrated in Table 1, salt (0.2 g) and butter (33 g) were mixed by hand for 5 minutes. The milk (15 ml), baking powder (2.0 g), vanilla (1.0 g) sugar (1.25 g) and whole eggs (1.25 ml) were meticulously mixed together. While continuously stirring, 65 ml of water was gradually added until the dough reached a desirable texture, slightly firm in consistency. The dough underwent kneading for 4 minutes on a clean, flat surface. Subsequently, it was manually rolled into sheets and shaped using a stamp cutting method. The resulting dough shapes were then placed onto greased trays and baked in an oven set at 180°C (Melese & Keyata, 2022).

Analysis of biscuits

Spread ratio

The thickness and diameter of each biscuit were measured at three different points using a composing stick (Sentez Teknik, Türkiye), and the average of each was calculated and the spread ratio was computed (Chauhan, Saxena, & Singh, 2015).

Specific volume

The specific volume of the biscuits was assessed via the seed replacement method, conducted 2 hours post-baking. Calculation of specific volume involved dividing the volume of the biscuits by their respective weight (AACC, 2000).

Scanned electron microscopy (SEM)

The morphological and structural characteristics of the biscuits were examined using a scanning electron microscope (Zeiss Gemini 500, Carl Zeiss Microscopy GmbH, Germany). Before imaging, the dry samples were coated with gold under vacuum conditions. Micrographs were obtained for each sample at different magnifications of 1.0kx and 5.0kx.

Sensory analysis

The sensory assessment of the biscuits prepared was carried out with the participation of 30 semi-trained panelists comprising staff and students from the Food Engineering department at Erciyes University. Prior to the evaluation session, the panelists received orientation regarding the sensory evaluation procedure. Subsequently, the panelists were presented with coded samples in a randomized sequence for the assessment of sensory characteristics including color, odor, taste, appearance fragility, and overall acceptability. Ratings were provided using a hedonic scale, ranging from 1 (extremely dislike) to 9 (extremely like).

Statistical analysis

The data obtained in this study were underwent statistical analysis using the ANOVA multiple comparison method via Minitab software (Minitab Ltd., Coventry, England). The Fisher's LSD test was employed to assess differences between means, with statistical significance indicated by p<0.05.

Results and Discussion

Powder properties of composite flours

The distinctive attributes of powdered products, encompassing loose bulk and tapped bulk density as well as the Hausner ratio, play a critical role in food formulation, preparation techniques, and storage parameters. Detailed findings elucidating these powder characteristics are presented in Table 2. Noteworthy is the observation that sample S1 exhibited the highest loose bulk density value, indicative of the impact of lentil flour inclusion in composite flours on this specific parameter.

Table 2. Powder properties of composite flours

Samples	Loose Bulk Density (g ml^{-1})	Tapped Bulk Density (g ml^{-1})	Hausner Ratio
C	0.46±0.01^{d}	0.65±0.01^{b}	1.43±0.00^{c}
S1	0.54±0.01^{a}	0.71±0.02^{a}	1.32±0.00^{e}
S2	0.50±0.01^{b,c}	0.74±0.01^{a}	1.47±0.00^{a}
S3	0.49±0.01^{c}	0.73±0.01^{a}	1.47±0.00^{b}
S4	0.52±0.01^{a,b}	0.73±0.01^{a}	1.39±0.00^{d}

* Different letters within a column indicate statistically significant differences between the data ($p < 0.05$).

The bulk density of powdered products holds paramount significance from economic, commercial, and functional perspectives. Ensuring a high bulk density in powder products is crucial for minimizing packaging volume, particularly during long-distance transportation, thereby resulting in savings in packaging material. Additionally, the density of a powder must be carefully considered in relation to container volume, packaging material requirements, and machine selection for processing, as emphasized in previous research (Göksel Saraç, Aslan Türker, & Dogan, 2020). Conversely, low bulk density is a critical consideration, particularly for instant food powders, as it serves as a key indicator of susceptibility to agglomeration or caking in food products (Sharma, Jana, & Chavan, 2012). Upon conducting calculations for loose and tapped bulk density evaluation, the sample (C) consisting solely of einkorn flour exhibited the lowest results for both analyses. Tapped bulk density ranged between 0.65 g ml^{-1} and 0.74 g ml^{-1}, with statistically insignificant differences observed in composite flours containing lentil flour (p>0.05). However, the tapped bulk density value of sample C differed significantly from these samples (p<0.05), a trend consistent with observations regarding loose bulk density, which also increased with the addition of lentil flours.

While soft wheat flour, being the least dense, may entail higher packaging costs due to increased space requirements per unit weight (Shittu, 2012), its lighter weight facilitates transportation. Furthermore, the low bulk density of wheat flour presents advantages in the preparation of complementary foods. The decreased bulk density of sample C, comprising only einkorn flour, can be attributed to its relatively low protein and moisture content (Owens, 2001). The structural strength of a powder plays a pivotal role, with powders possessing strong structural integrity resisting agglomeration and exhibiting low bulk density when dispersed in a conveying system. Conversely, structurally weak powders settle easily, resulting in higher bulk density. High friction between particles typically leads to lower bulk density, a phenomenon corroborated by previous studies (Abdullah & Geldart, 1999). Furthermore, the evaluation of flow behaviors through Hausner ratio analysis, derived from bulk and compressed density data, reveals distinct flow characteristics among the samples. Low Hausner ratio (<1.25) indicates better flow properties than higher ones; 1.25 to 1.5 indicates moderate flow characteristics and more than 1.5 indicates poor flow (Mahesh, 2018). Einkorn flour and composite flours with varying compositions demonstrate moderate flow behavior, as indicated by the Hausner ratio classification.

Water and Oil Absorption Capacity

Figure 1 illustrates the WAC values of composite flours formulated using einkorn flour alongside green, red, and yellow lentil flours. Notably, the S2 sample exhibited the highest WAC value (2.42 ± 0.41), whereas the S3 sample recorded the lowest value (1.43 ± 0.13). With the exception of red lentil flour, all other lentil flours significantly ($p<0.05$) augmented the WAC value of einkorn flour-based composite flours. This notable increase in water absorption capacity renders these composite flours viable for the production of bakery foods like bread and biscuits (Bello & Ekeh, 2014; Eriksson, Koch, Tortoe, Akonor, & Baidoo, 2014). In light of this, the composite flour containing green lentils and einkorn flour, boasting the highest WAC value, emerges as a promising alternative for the production of bakery goods such as biscuits and bread.

Absorption properties are primarily influenced by the chemical composition of the sample, which includes carbohydrates, proteins, and fiber that constitute the majority of the non-fat portion of food solids (Sciammaro et al., 2021). Powdered particles are composed of one or more biomolecules, such as lipids, proteins, carbohydrates and minerals. The impact of water on these particles depends on their composition and their capacity to adsorb water from the air (Yu, Chan, Gengenbach, & Denman, 2017). Moreover, the arrangement of biomolecules on the particle surface influences their interaction with water and other particles (Murrieta-Pazos et al., 2012). Proteins and lipids are mainly hydrophobic (Crowley, Gazi, Kelly, Huppertz, & O'Mahony, 2014). The chemical profiles of the powders are detailed in the Materials and Methods section. Composite flours showed varying lipid contents, with RLF having the highest at 1.5%. YLF was noted for its significantly lower carbohydrate content. Consequently, powders with higher protein and lipid content exhibit greater stability at high relative humidity and are less soluble in pure water (Chandrapala, Zisu, Palmer, Kentish, & Ashokkumar, 2014). In contrast, most minerals and carbohydrates, particularly saccharides, are hydrophilic and form soluble powders (Fournaise et al., 2020).

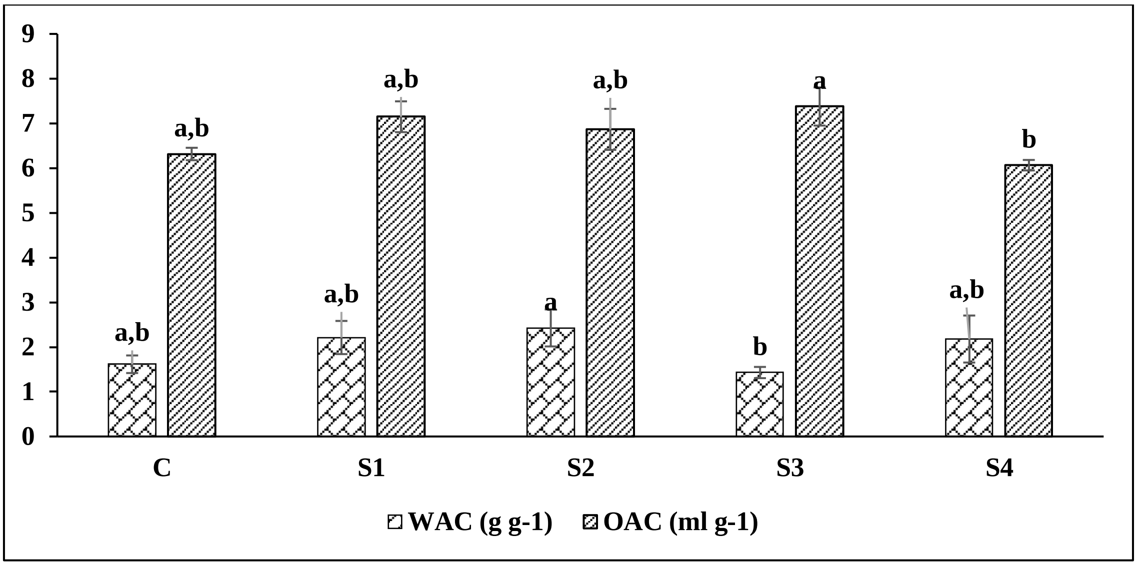

Figure 1. Water and oil absorption capacity of composite flours

The oil absorption capacity (OAC) of a foodstuff is pivotal in determining its ability to assimilate oil during biscuit development. With the inclusion of lentil flours in the formulation, the OAC content exhibited an increase, notably peaking in the S3 sample (Figure 1). This heightened OAC content within the composite flour may stem from the elevated protein content inherent in the investigated lentil flours. Such elevation could be attributed to the presence of proteins exposing more nonpolar amino acids to the oil, thereby amplifying hydrophobicity and consequentially enhancing oil absorption (Oluwamukomi, Oluwalana, & Akinbowale, 2011). Oil absorption capacity, calculated as the absorbed fat weight per protein or flour weight, hinges on the binding of fat by nonpolar amino acids residing in protein side chains. Elevated oil absorption capacity not only augments texture but also mitigates yield losses in processed foods like baked goods (Foschia, Horstmann, Arendt, & Zannini, 2017). Within this study, oil absorption capacities of composite flours were ranged from 6.07 ml g^{-1} to 7.37 ml g^{-1}. The water and oil absorption capacities of food proteins are depend on factors such as amino acid composition, protein structure, and surface polarity or hydrophobicity (Du, Jiang, Yu, & Jane, 2014a). Enhanced OAC not only refines texture but also contributes to favorable taste and mouthfeel in food products (Appiah, Asibuo, & Kumah, 2011). Consequently, a composite flour blend comprising einkorn flour and red lentil flour, boasting superior oil absorption capacity, may outperform other flours as a flavor enhancer. Moreover, the S3 sample's high oil absorption capacity suggests potential utility in products necessitating substantial oil absorption. However, Kinsella and Melachouris (1976) suggest that lipids bind more effectively to proteins exhibiting greater hydrophobicity, hinting at the affinity between nonpolar amino acid side chains and fat paraffin chains. Thus, it can be inferred that red lentil flour, with its heightened oil absorption capacity, probably has a higher amount of non-polar side chains in its protein molecules.

Functional properties of composite flours

Table 3 exhibits the variability in swelling power among composite flours, ranging from 12.37% to 14.25%. Notably, the type of lentil flour incorporated into the formulation did not yield statistically significant differences in the swelling power of the composite flours, as evidenced in Table 3. The swelling power values observed in this study align with those reported for wheat flour (12.75%) by Enwere (1998). The augmentation in swelling power within composite flours might be due to the formation of protein-amylose complexes. Swelling power serves as an indicator of granule absorption post-heating, thereby delineating the water retention capacity of starch molecules with hydrogen bonding, a phenomenon linked to starch and amino acid concentration (Iwe, Onyeukwu, & Agiriga, 2016). Variations in flour swelling power may hinge on the amylose/amylopectin ratio and their respective properties concerning conformation, length and degree of branching and molecular distribution (Hoover, 2001).

The foaming capacity of a food or flour is measured by the extent of interfacial area generated during its agitation. Primarily, proteins are accountable for foaming. Foaming capacity and stability typically depend on the interfacial film forged by proteins, which facilitates the suspension of air bubbles and retards the coalescence rate (Awuchi, Igwe, & Echeta, 2019). Notably, the composite flour containing red lentil flour (S3) exhibited the highest foam capacity at 16.00%, followed by samples S4, S2, S1, and C, respectively (Table 3). Moreover, statistically significant differences in foam capacities among the samples was observed (p<0.05). This differences may stem from the variances among different lentil flours and the distinct physical properties of their principal proteins.

Table 3. Functional properties of composite flours

Samples	**Swelling Power (%)**	**Foaming Capacity (%)**	**Dispersibility (%)**
C	14.25±1.79^{a}	10.83±0.24^{c}	71.50±0.71^{a,b}
S1	14.15±1.14^{a}	10.83±0.24^{c}	72.50±0.71^{a}
S2	12.37±2.22^{a}	11.50±1.18^{b,c}	67.50±0.12^{c}
S3	14.22±2.69^{a}	16.00±1.41^{a}	73.50±0.71^{a}
S4	12.98±2.82^{a}	14.00±1.41^{a,b}	69.00±1.41^{b,c}

* Different letters within a column indicate statistically significant differences between the data (p < 0.05).

The protein dispersion in red lentil flour can diminish surface tension at the water–air interface, consistently resulting in the formation of a cohesive film enveloping the air bubbles in the foam (Kaushal, Kumar, & Sharma, 2012).

Legume/pulse flours are characterized by their elevated levels of protein and starch content, a factor that impacts the gelling capacity of these flours. This phenomenon arises from the competitive physical interplay between starch gelation and protein gelatinization for water absorption (Kaushal et al., 2012). The composite flour incorporating red lentils and einkorn flour demonstrated the highest foaming capacity, signifying that the protein content and the formation of protein-carbohydrate complexes in legumes might impact their foam capacity and stability. Red lentil flour exhibited commendable foam stability, likely attributable to the elevated surface activities of soluble proteins in continuous water phases (Kaur & Singh, 2005).

Table 3 presents the dispersibility results for both composite flour and einkorn flour. The findings indicate a notable (p < 0.05) alteration in flour dispersibility upon incorporating einkorn flour with red, yellow, and green lentil flour. Specifically, the composite flour formulated with red lentil flour exhibited the highest dispersibility rate, recorded at 73.50%.

Spread Ratio and Specific Volume of the Biscuits

The variations in composite flour compositions significantly influenced both the spread ratio and specific volume of the biscuits, as presented in Table 4. Throughout this study, the spread ratio of the biscuits ranged from 4.72 to 7.20, representing a tangible physical attribute. It's noteworthy that the control sample demonstrated a significantly (p < 0.05) lower spread ratio in contrast to the composite biscuits. This observation aligns with the findings of Durojaiye, Abubakar, Nwachukwu, Mohammed, and Ibrahim (2018) who stated that augmenting the addition of Bambara nut flour and black-eyed pea flour led to a higher spread ratio compared to whole wheat flour biscuits. Similarly, Chauhan, Saxena, and Singh (2016) observed an increase in spread ratio with higher substitution rates of wheat flour with amaranth flour. The lower spread ratio in control biscuits implies that the starches in the control (einkorn flour) exhibit higher hydrophilicity compared to composite flours, thereby resulting in the reduced spread ratio of einkorn (control) biscuits. Differences in protein quality and water absorption properties can alter the water absorption capacity of flour and subsequently affect its spread ratio. Conversely, the robust water-binding property of fiber may also impact biscuit spread ratio (Ojha & Thapa, 2017). Spreading ratio is an important feature in predicting the quality and rising ability of flour used in the preparation of biscuits (Adeola & Ohizua, 2018). According to the Melese and Keyata (2022), the higher the value of the spread ratio, the more desirable the product and biscuits boasting a higher spread ratio are typically preferred. Hence, among the biscuits formulated with a mixture of all lentil flours (S4) and exhibiting the highest spread, is considered one of the most preferred.

Table 4. *Spread ratio and specific volume values of the biscuits*

Samples	**Spread ratio**	**Specific volume (cm^3 g^{-1})**
C	4.72 ± 0.11^{c}	1.70 ± 0.13^{a}
S1	6.87 ± 0.29^{a}	1.24 ± 0.11^{b}
S2	7.18 ± 0.06^{a}	$1.04 \pm 0.03^{c,d}$
S3	5.77 ± 0.24^{b}	$1.16 \pm 0.02^{b,c}$
S4	7.20 ± 0.35^{a}	0.92 ± 0.04^{d}

* Different letters within a column indicate statistically significant differences between the data ($p < 0.05$).

A biscuit of optimal quality is anticipated to exhibit a substantial specific volume, denoting the ratio of biscuit volume to biscuit weight (Ma & Baik, 2018). Specific volume measurements for control biscuits (1.70 cm^3 g^{-1}) were markedly higher compared to the lower values recorded for composite biscuits (0.92–1.24 cm^3 g^{-1}) (Table 4). The reduced volume observed in composite biscuit flour samples might stem from the reduced gluten content in the dough, impeding gas retention (Melese & Keyata, 2022). These findings consistent with those reported by Ostermann-Porcel, Quiroga-Panelo, Rinaldoni, and Campderrós (2017). In their study, researchers noted that, similar to our findings, elevating the addition of okara led to cookies with the lowest specific volume.

Microstructure of biscuits

Product attributes such as cell density, structural uniformity and size significantly influence the sensory characteristics of baked goods, including biscuits. SEM images illustrating the internal cross-sectional area of biscuits are provided in Fig. 2. The microstructural assessments conducted on biscuits incorporating einkorn and lentil flours revealed alterations in their structure, which varied depending on the type of lentil flour incorporated into the dough formulations.

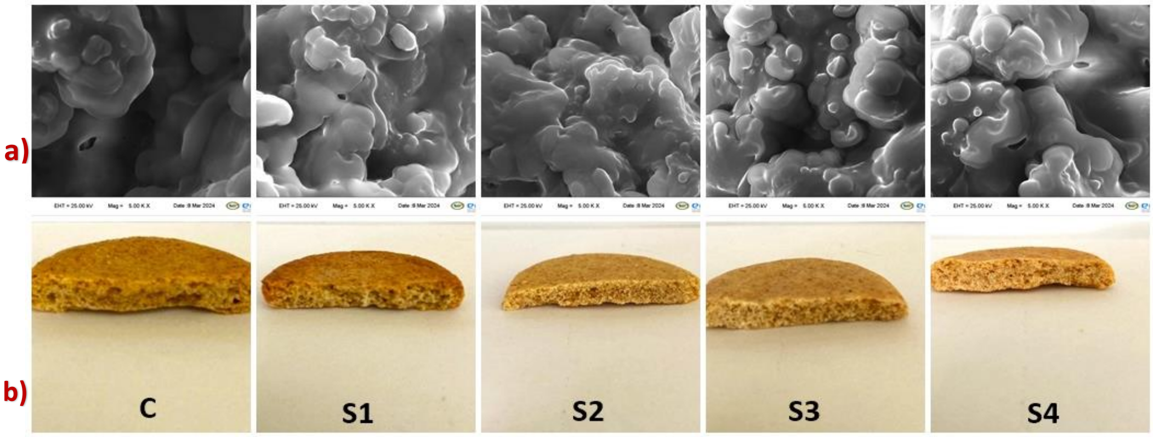

Figure 2. SEM images (a) and cross-sectional views (b) of biscuits

The control biscuit notably displayed a crumbly texture, contrasting with the other samples, which featured a more cohesive starchy-gluten composite network. Analysis of the biscuit micrographs (Figure 2a) revealed that the structure of C exhibited a smaller, more uniform, and smoother network compared to S1, S2, S3, and S4, indicating that the malting and fermentation processes induced changes contributing to the uniform shape in the respective samples. The observed pits in biscuit samples containing lentil flour may be attributed to the enzymatic hydrolysis of proteins (yielding amino acids) and starch (yielding sugars) (Claver, Zhang, Li, Zhu, & Zhou, 2010).

Sensory Evaluation of the Biscuits

The mean sensory assessments for both formulated biscuits and control samples, conducted by semi-trained panelists, are depicted in Figure 3a. Color serves as a crucial factor influencing the initial acceptability of baked goods. Notably, the color score of formulated biscuits exhibited an increment from 5.61 to 6.52. Furthermore, among the S1 coded biscuit samples containing einkorn and green lentil flour, the highest color score was observed. However, it's worth noting that the combination of red, yellow, and green lentil flours led to a decrease in consumer color preference.

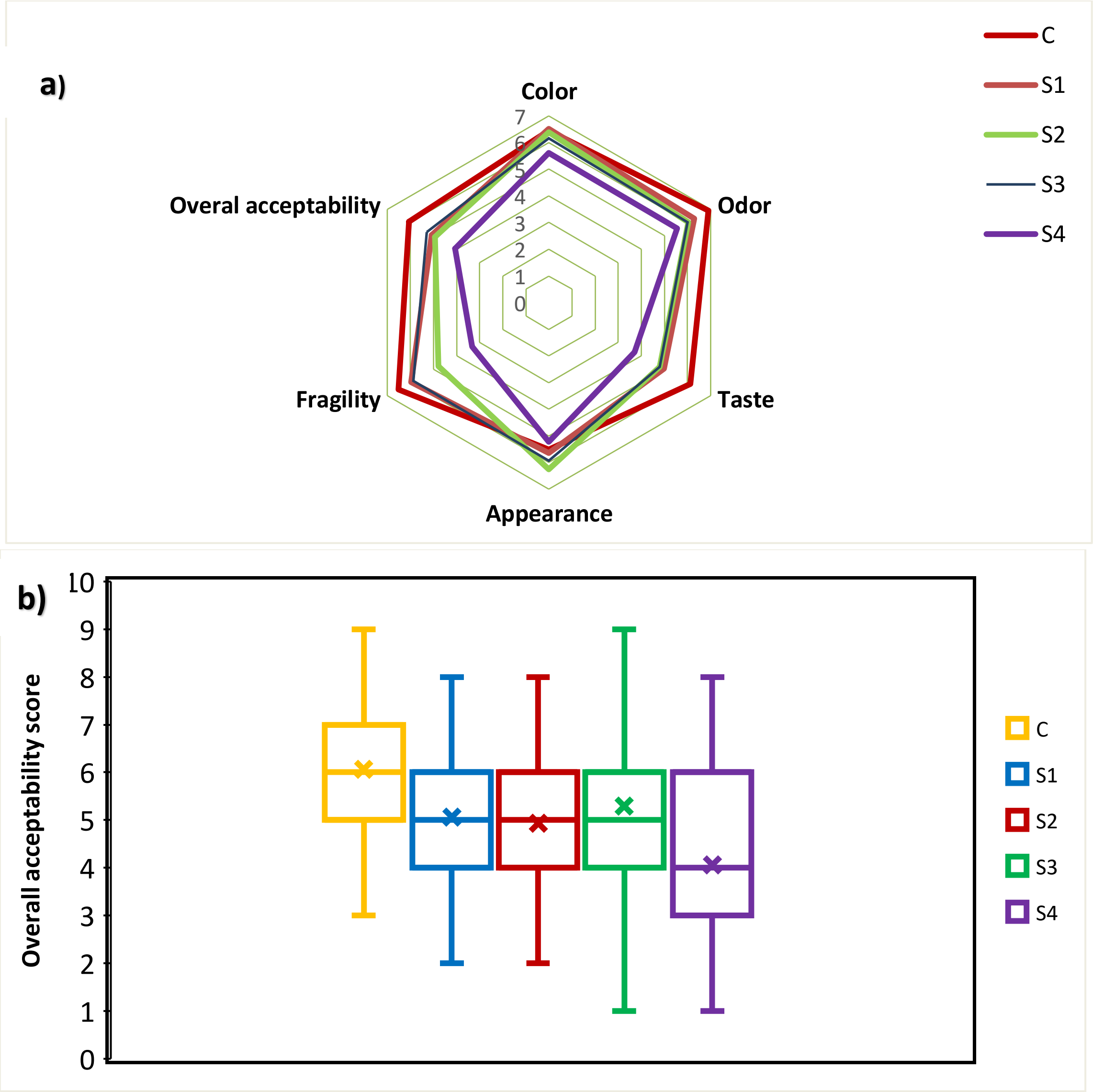

Figure 3. The sensory attributes (a) and overall acceptability (b) scores of the biscuits

Figure 3a illustrates the sensory odor scores ranging from 5.54 to 6.90. Notably, the variation in formulation led to a significant ($p < 0.05$) disparity in biscuit odor.

The taste scores for control samples and formulated biscuits ranged from 3.70 to 6.12, as depicted in Figure 3a. Notably, the control flour biscuit achieved the highest taste score in comparison to the composite flour samples. As the lentil flours were incorporated, there was a decrease in taste score, with the lowest score recorded at S4. This could be attributed to the lentil flavors imparted by the utilized lentils.

Sensory panelist awarded the highest fragility score to the control biscuit comprising einkorn flour. Nonetheless, with the increased addition of composite flour, the score declined (Figure 3a).

Moreover, semi-trained panelist conducted evaluations on the biscuits regarding overall acceptability. The control biscuit scored 6.06 (±1.55), whereas the biscuit formulations with einkorn and green lentil flour scored 5.06 (±1.52), einkorn and yellow lentil flour scored 4.93 (±1.61), einkorn and red lentil flour scored 5.29 (±1.75), and biscuits with einkorn and all lentil flour scored 4.06 (±1.98) (Fig. 3b). Notably, adding red lentil flour to biscuits led to a product with comparatively consistent overall acceptability scores among the panelists. Additionally, its elevated mean score value indicates its sensory characteristics are similar to those of the control product. Such a bakery product holds promise for broad consumer preference (Figure 3a-b). Conversely, panelist showed a preference against biscuits incorporating all lentil flours together, as evidenced by their lower scores in color, odor, brittleness, and taste. Overall, the sensory evaluation clearly indicated a preference for biscuits containing red lentil flour, as they lacked apparent undesirable sensory attributes in the baked product with this flour addition.

In summary, this research consists of two key parts. The first part involved evaluating the physicochemical and powder flow properties of composite flours made with various lentils and einkorn flour. The second part focused on the physicochemical and sensory properties, as well as the morphological structures, of biscuits derived from these composite flours. The composite flour identified as S2, prepared with yellow lentil flour, exhibited the highest OAC, beneficial for enhancing texture and reducing yield losses in processed foods like baked goods. Similarly, the composite flour containing green lentils and einkorn flour showed a significant increase in WAC, making it suitable for bakery foods such as biscuits and bread. Additionally, bulk density considerations are crucial for economic and functional aspects of packaging and processing, while the Hausner ratio provides insights into the flow properties of the flours. These comprehensive evaluations indicate that composite flour blends of einkorn and lentil flours are promising candidates for use in various bakery products.

Conclusion

This study aims to formulate biscuits with improved physicochemical properties and sensory acceptability using composite flours incorporating einkorn flour along with green, red, and yellow lentil flours as base ingredients. The inclusion of lentil flours in the formulation led to an increase in OAC content, reaching its peak in sample S3, especially containing red lentil flour. This high OAC content in the composite flour may stem from the high protein content inherent in the investigated lentil flours' nature. The spread ratio of biscuits in this study is a true physical characteristic ranging from 4.72 to 7.20. The low spread ratio in control biscuits indicates that the starches in the control (einkorn flour) displayed higher hydrophilicity compared to the composite flours, thus resulting in the decrease in spread ratio of einkorn (control) biscuits. Differences in protein quality and water absorption properties can alter the flour's water absorption capacity and consequently affect the spread ratio. Biscuits prepared with einkorn flour, along with all lentil flours, which exhibited the highest spread ratio, can be considered the most preferred products. Overall, sensory evaluation clearly indicated a preference for biscuits containing red lentil flour, as they lacked obvious undesirable sensory properties in the baked product due to this flour addition. Consequently, biscuits incorporating composite flour were not as well received. It may be advantageous to experiment with a lower ratio of composite flour in future formulations.

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Authors' Contribution: Duygu ASLAN TÜRKER was responsible for selection of the research topic, conducting experiments, data collections and analysis, writing and reviewing the manuscript.

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