Oat Milk as A Functional Food Produced from Sprouted Oat Grains

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ABSTRACT

This study was carried out to evaluate the effect of sprouting period on the nutritional value (proximate chemical composition, bio-minerals, amino acids and bio-active components (phenolics and flavonoids) content) of oat grains and their produced milk. The sprouting process improves the nutritional value of oat grains by increasing the sprouting period. On the other hand, oat milk produced from sprouted oatmeal followed the same trend as sprouted oat grains. As for mineral content, it showed the increasing trend during the sprouting process as well as for the milk produced from sprouted milk, i.e., Fe (1.8 fold), Ca (1.3 fold), Mg (1.6 fold), Cu (3.4 fold) and Mn (1.3 fold). The HPLC analysis showed that the sprouting process enhanced the phenolic and flavonoid components as quinic, cinnamic, apigenin, diosmin, rutin, coumaric, pyrochatechol, phenanthrene and ferulic acid. It could be noted that the sensory properties and acceptability of oat milk produced from sprouted oat meal were improved. It could be suggesting that sprouting is an a simple and inexpensive process; however, it enhances the nutritional, antioxidant activity and sensory properties of oat milk, making it an excellent choice milk allergies and vegetarians.

Keywords: functional food, oat milk, sprouting process, nutritional value, phenolic and flavonoid compounds.

INTRODUCTION

An estimated 68% of the world's adult population suffers from lactose malabsorption. Lactose intolerance is a common condition caused by a person's decreased ability to digest lactose, due to reduced lactase production in the body (Misselwitz *et al.*, 2013). Along with lactose intolerance, milk allergy remains another serious problem in modern society. It is estimated that 3% of children suffer from it, and can present with various symptoms upon consumption including life-threatening anaphylaxis (Høst, 2002).

Plant-based milks are considered environmentally friendly compared to animal milks because animal farming is accountable for the production of methane gas through enteric fermentation, which has a greenhouse gas effect 28 times utmost than carbon dioxide (Grossi *et al.*, 2019). The industry based on animals are familiar to be accountable for 12.5% of global greenhouse gas emissions, however, the beef and dairy sectors are responsible for two-thirds of these emissions (Rojas-Downing *et al.*, 2017). This has led some individuals to reduce their consumption of animal products and turn to plant products, including plant milk.

On the other hand, some individuals rely solely on plant-based sources for their consumption due to health considerations, animal welfare concerns, and/or diversity-seeking motivations. A life cycle assessment study conducted for the annual sustainability report found that oat milk production reduces greenhouse gas emissions by 80%, takes up 80% less space, and uses 60% less energy than cow's milk (Oatly, 2017).

Sprouting grains is one of the most effective and least economical ways to increase the nutrient content of grains. It also enhances their bio-availability, reduces anti-nutritional compounds and adds a new flavor to them. This increases the edibility of grains as well as their health benefits for humans (Gunathunga *et al.*, 2024).

Oats have individual characteristics compared to other main cereals, including higher levels of protein than many other grains, an equiponderant amino acid composition, and the obscurity of gluten and allergens (Boukid, 2021). So, oats are a substitute source of protein to substitute of traditional meat and dairy products. Furthermore, oats contain vitamins, lipids, antioxidants, and soluble dietary fiber (β-glucans) that help decrease blood cholesterol levels. Oats can grow in a variety of environmental conditions and on different types of soil. This versatility is likely to increase oats' importance in the future, as climate change makes grain cultivation more challenging (Holopainen-Mantila *et al.*, 2024). Oat milk is an aqueous extract of oats and is considered an emerging bio-based food (Bocchi *et al.*, 2021).

The main objective of this research is to study the use of sprouted oats at different time periods to produce oat milk and its effect on the nutritional value and sensory properties of oat milk. Making this product an excellent choice for vegetarians.

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MATERIAL AND METHODS

Materials:

Oat (*Avena sativa*) grains were obtained from the Agricultural Research Center, Giza, Egypt. After cleaning and separating of non-oat seeds, the whole oat grains were stored at 4°C to minimize any changes in composition.

Technological treatments:

Preparation of Oats Flour:

Oat grains were cleaned and sorted to remove stone, dust particles, and broken grains then washed with tap water three times then soaked in water for 24 hours, changing soaking water every 8 hours, then rinsed with running tap water after soaking. Water was separated well and then oat grains were dried in the oven at 60°C for 24 hours. The dried oats grains were milled, sieved as particles size smaller than 0.5 mm and packed into polyethylene bags and stored at -18°C until use, which served as a control.

Sprouting of Oat Grains:

Oat grains were cleaned, sorted, washed and soaked in sterile tap water (1:6 w/v) for 24 hours at room temperature. Water was separated well and grains were placed in muslin cloths to sprout. Oat grains were sprouted for 1, 2 and 3 days. During sprouting, the grains are turned once daily and sprayed with water twice daily. After the oats had sprouted, the grains were dried in the oven at 60°C until dry, then milled, sieved and packed into polyethylene bags and stored at -18°C until use.

Oat Milk Preparation Methods

Oat Milk Extraction:

Oat flour was blended with different ratios of water (1:4, 1:6, and 1:8 w/v) using a blender (Molineux, France). The oat milk mixture was then filtered through a double-layered muslin cloth to obtain oat milk. Oat milk was heated at 90°C for 10 minutes, and incipient sensory evaluation was conducted to select the best ratio. The results showed that 1:8 was the best choice.

Sprouted Oat Milk Extraction:

The different sprouted oats were mixed with water at 1:8 (w/v) ratios using a mixer grinder (Molineux, France). Oat milk slurry was filtered through a double-layered muslin cloth to obtain oat milk. The filtered oat milk was packed into glass bottles heated at 90°C for 10 min, then heated at 100°C for 5 min and stored at -18°C until use (Babolanimogadam *et al*., 2023). The same treatment was performed on oat flour as a control sample. According to the period of the sprouting process (1, 2 and 3 days), the sprouted oat grains were named O_2, O_3 and O_4, while the control oat flour sample was named O_1. In the same trend the produced oat milks are named OM_2, OM_3 and OM_4; however, the control oat milk sample, which was made from oat flour named OM_1.

Methods of analysis:

Proximate composition:

Moisture, total lipids, protein, mineral and ash contents were determined according to A.O.A.C. (2005), while carbohydrate content was estimated by Chaplin and Kennedy (1994) and total carbohydrates were calculated by differences. Protein content was obtained by multiplying the proportion of total nitrogen by 5.83 for oats grains and 6.24 for oat milk. Total soluble solids (T.S.S) were estimated by a handheld refractometer (HI 96801, Romania). Total phenolic compounds were determined by the method of Kaur and Kapoor (2002).

Furthermore, the energy value (kcal per 100 ml) of samples was calculated by using Equation (WHO/FAO, 2003):

$$\text{Energy value} = (\text{Protein\%} \times 4) + (\text{Carbohydrates\%} \times 4) + (\text{Fat\%} \times 9) \qquad (1)$$

Total carbohydrates were calculated by difference using Equation (WHO/FAO, 2003):

$$\text{Total carbohydrates (on a dry basis)} = 100 - (\text{protein} + \text{fat} + \text{ash}) \qquad (2)$$

Determination of Amino acid profile:

Preparation of hydrolyzed amino acids was performed according to the method of Csomos and Simon-Sarkadi (2002). The dried defatted grinding sample (0.2g) was hydrolyzed with 10 mL HCL (6N) in a sealed tube, heated at 105°C for 12 h. The resulting solution was diluted to 25 mL with deionised water. After filtration, five ml of hydrolysate was evaporated in a water bath until to was free from HCL. The samples and standards were diluted with 0.2 mL citrate buffer pH 2.2, to the proper concentration. Amino acids were separated on an INGOS amino acid analyzer.

Identification of phenolic and flavonoid compounds by HPLC:

HPLC analysis was performed using the system Thermo (Ultimate 3000) consisted of: pump, an automatic sample injector, and an associated DELL-compatible computer supported with Cromelion7 interpretation program. A diode array detector, DAD-3000, was used. The Thermo-hypersil reversed phase C18 column 2.5× 30 cm was operated at 25ºC. The Mobile phase consists of 0.05% Trifluoroacetic acid/Acetonitrile (solvent A) and distilled water (solvent B). The UV absorption spectra of the standards as well as the samples were recorded in the range of 230–400 nm. Samples and standards solutions, as well as the mobile phase, were degassed and filtered through a 0.45 µm membrane filter (Millipore). Identification of the compounds was done by comparison of their retention time and UV absorption spectrum with those of the standards (Biswas *et al.,* 2013).

Sensory evaluation of oat milk:

Sensory assessments of prepared samples were evaluated by 20 panellists of the staff of Agriculture Industrialization Unit, Desert Research Center, Cairo, Egypt. Panellists were asked to evaluate color, odor, taste, texture and overall acceptability, of all samples according to the method described by ISO 8589 (1988).

Statistical analysis:

All data were expressed as mean values. Statistical analysis was performed using the SPSS (Statistical Program for Sociology Scientists) Statistics Version 20 for computing one way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test with $p \leq 0.05$ being considered statistically significant (IBM Corp, 2011).

RESULTS AND DISCUSSION

Oats have gained worldwide recognition as a healthy and nutritious raw material food, due to their equiponderant nutritional composition. It's worth noting that the nutritional structure of oats varies depending on the species, strain, and growing conditions (Cui *et al.*, 2023). As pointed out in Table (1), oats flour (O_1) contained high levels of protein (11.54%), fat (9.20%), total carbohydrates (71.18%) and crude fiber (45.31%). Meanwhile, the sprouting process showed significant improvement ($p \leq 0.05$) in most compounds with increasing sprouting period. Moisture content (from 4.40 to 6.90%), protein (from 11.54 to 14.40%) and ash (from 3.68 to 4.25%) in oatmeal sprouted with the increase of sprouted period compared to oats flour. However, total carbohydrates were reduced with the increase of sprouting period and increasing at the end of sprouting period this may be due to an increase or decrease in oat combination such as protein, moisture, fiber, fat and ash during sprouting. These results were consistent with Faraj *et al.* (2013), who demonstrated that germination of oats grains increases moisture and protein. They attributed the increase in protein with longer germination period to the breakdown of stored protein and the induction of new protein and other substances that the young plant needs for growth. The increase in ash content indicates an increase in mineral content resulting from their bio-availability during sprouting, as shown in Table (2).

Total phenols increased from 0.28 to 1.03% (3>fold) in oatmeal sprouted with increasing sprouting period compared to oats flour. El-Refai *et al.* (2012) indicated that the increase in phenolic content with increasing germination period is due to the production of a variety of bio-logically active components, which improve their nutritional and functional properties, thus enhancing their nutritional value.

In general, from the above data, it can be clearly concluded that the sprouting process played a role in improving the chemical composition of oat grains, thus enhancing their nutritional value.

Minerals play an important part in promoting health. Grains such as oats are rich in minerals. Unless their bio-availability is low by virtue of the existence of anti-nutritional factors (Faraj *et al.*, 2013). Mineral contents of oats flour (O_1) and sprouted oatmeal with increasing the sprouting period were estimated, and the data are elucidated in Table (2). Sprouting process significantly ($p \leq 0.05$) enhances the concentration of mineral elements (iron, calcium, magnesium, copper and manganese) with increasing sprouting period.

Data in Table (2) indicate a significant increase ($p \leq 0.05$) in bio-mineral contents of Fe (from 247.5 to 408.8 ppm), Ca (from 1156.3 to 1835.0 ppm), Mg (from 1125.0 to 1552.5 ppm), Cu (from 13.8 to 30.0 ppm) and Mn (from 35.0 to 50.0 ppm) in sprouted oatmeal with an increase in sprouting period compared to oats flour. Besides, Zn (75.0-40.0 ppm) decreased in oatmeal sprouted with increased sprouting period compared to oats flour.

Table 1. Mean values of proximate composition of sprouted oatmeal during the process period

Components (%)	O_1	O_2	O_3	O_4
Moisture content	$4.40^{d} \pm 0.25$	$5.50^{c} \pm 0.11$	$6.25^{b} \pm 0.20$	$6.90^{a} \pm 0.12$
Total Fat	$9.20^{a} \pm 0.25$	$8.68^{b} \pm 0.14$	$7.17^{c} \pm 0.22$	$4.20^{d} \pm 0.15$
Proteins	$11.54^{d} \pm 0.40$	$12.07^{c} \pm 0.25$	$13.73^{b} \pm 0.50$	$14.40^{a} \pm 0.25$
Ash	$3.68^{c} \pm 0.01$	$3.74^{bc} \pm 0.01$	$3.80^{b} \pm 0.02$	$4.25^{a} \pm 0.01$
Total carbohydrates[1]	$75.58^{b} \pm 0.01$	$75.51^{c} \pm 0.02$	$75.34^{d} \pm 0.05$	$77.15^{a} \pm 0.03$
Crude fiber	$45.31^{a} \pm 0.20$	$41.95^{b} \pm 0.10$	$40.69^{c} \pm 0.05$	$36.60^{d} \pm 0.04$
Total Phenols	$0.28^{d} \pm 0.01$	$0.52^{c} \pm 0.01$	$0.62^{b} \pm 0.02$	$1.03^{a} \pm 0.03$

Means ± standard deviation followed by different small letters in the same row (effect of increased sprouted period on sprouted oatmeal compared to oat flour) are significantly different by Duncan´s multiple test ($p \leq 0.05$).

[1]Total carbohydrates (on a dry basis) = 100 – (protein + fat + ash).

Table 2. Mineral contents of sprouted oatmeal during process period

Treatment	Bio-minerals (ppm)					
	Fe	Ca	Mg	Zn	Cu	Mn
O_1	$247.5^{d} \pm 0.50$	$1156.3^{d} \pm 0.30$	$1125.0^{d} \pm 0.44$	$75.0^{a} \pm 0.50$	$13.8^{d} \pm 0.03$	$35.0^{c} \pm 0.02$
O_2	$332.5^{c} \pm 0.20$	$1681.3^{b} \pm 0.25$	$1431.3^{c} \pm 0.50$	$65.0^{b} \pm 0.17$	$25.0^{c} \pm 0.02$	$48.8^{b} \pm 0.01$
O_3	$343.8^{b} \pm 0.25$	$1631.3^{c} \pm 0.15$	$1512.5^{b} \pm 0.25$	$63.8^{c} \pm 0.10$	$27.5^{b} \pm 0.05$	$48.8^{b} \pm 0.02$
O_4	$408.8^{a} \pm 0.30$	$1835.0^{a} \pm 0.50$	$1552.5^{a} \pm 0.31$	$40.0^{d} \pm 0.21$	$30.0^{a} \pm 0.01$	$50.0^{a} \pm 0.03$

Means ± standard deviation followed by different small letters in the same column (effect of increased sprouted period on sprouted oatmeal compared to oat flour) are significantly different by Duncan´s multiple test ($p \leq 0.05$).

In the same vein, El-Refai *et al.* (2012) indicated that the germination process increases the content of mineral elements, especially calcium, iron and magnesium. This can be attributed to the activity of enzymes and the bio-synthesis process during germination (Gabriel and Akharaiyi, 2007).

HPLC analysis of phenolic and flavonoid compounds in oats flour and sprouted oatmeal during the sprouting process was determined, and the data were shown in Fig. (1). Sprouting promotes most compounds, producing the highest levels of key flavonoids: apigenin (2.2111 mg/g), rutin (5.5325 mg/g) and hisperidin (13.6175 mg/g). Phenolic acids followed a similar trend, with quinic acid increasing >5-fold as well as the production of individual components, such as cinnamic and resorcinol acid, which increased 26-fold and 10-fold at the end of the sprouting period, respectively.

HPLC analysis showed sprouting-induced variation in particular phytochemicals. While oats flour include quinic acid (0.0043 mg/g) and ellagic acid (0.0006 mg/g), sprouting increased most phenolics (quinic acid: 0.0213; ellagic acid: 0.0011 mg/g) and created new compounds such as cinnamic acid (0.0026 mg/g), resorcinol acid (0.0020 mg/g) and coumaric acid (0.0435 mg/g).

Furthermore, flavonoid compounds levels: hisperidin acid increasing >6-fold, apigenin acid increasing >3.5-fold, diosmin acid increasing >3-fold and rutin acid increasing >2-fold at the end of the sprouting period. These results are in agreement with Beart *et al.* (1985), who stated that the variation in the proportion of phenolic compounds must be due to increased enzymatic activity during germination processes.

Lastly, the above data showed that increasing the sprouting period improved the quality and quantity of phenolic and flavonoid compounds in oat grains, thus increasing their antioxidant capacity and activity.

Oat protein is comparable in quality to soy protein, and the World Health Organization has recognized it as comparable to egg, milk, and meat protein (Cui *et al.*, 2023). Additionally, oat protein equip a superior balance of essential amino acids for humans compared to most other grains, including primarily leucine (25.61 mg/g), valine (31.54 mg/g), lysine (16.84 mg/g), histidine (10.84 mg/g) and phenylalanine (13.37 mg/g), as shown in Table (3). Furthermore, sprouting oat grains changes the protein composition, affecting the amino acid content of the grain.

Results in Table (3) indicated a decrease in all amino acid content in oat grains during the sprouting period, except methionine, which increased from 0.31 to 1.32 mg/g. The decrease was noticeable in valine (31.54 to 8.99 mg/g), glutamic acid (67.36 to 25.62 mg/g) and aspartic acid (23.68 to 9.26 mg/g).

The decrease in the content of amino acids may be associated with the fact that the cumulative amino acids could be utilized for other metabolic processes, like the synthesis of new proteins or other bio-chemical reactions, which lessen their concentration (Ospankulova *et al.*, 2025).

Bagarinao *et al.* (2024) indicated that although oat grains experienced a significant increase in protein content upon germination, essential amino acids decreased by 15.35%, with a significant decrease in total non-essential amino acids (17%). This increase in protein content, accompanied by a decrease in non-essential amino acids, can be partially explained by the increased amount of non-protein nitrogen.

Chemical composition analysis of oat milks produced by oats flour (OM_1) and sprouted oatmeal with increasing sprouting period was determined, and the data are presented in Table (4). Sprouting significantly enhanced ($p \leq 0.05$) the major constituent, especially bio-active components.

In Table (4), the major compounds of oat milks produced by sprouted oatmeal were increased compared to oat milks produced by oat flour as a result of the sprouting process. Total soluble solids were increased to 5.30 °Brix (1.9-fold), protein to 3.10% (1.24-fold), ash to 0.29% (1.12-fold), carbohydrates to 3.05% (1.17-fold) and total phenolics to 0.35% (1.46-fold) at the end of the sprouting period.

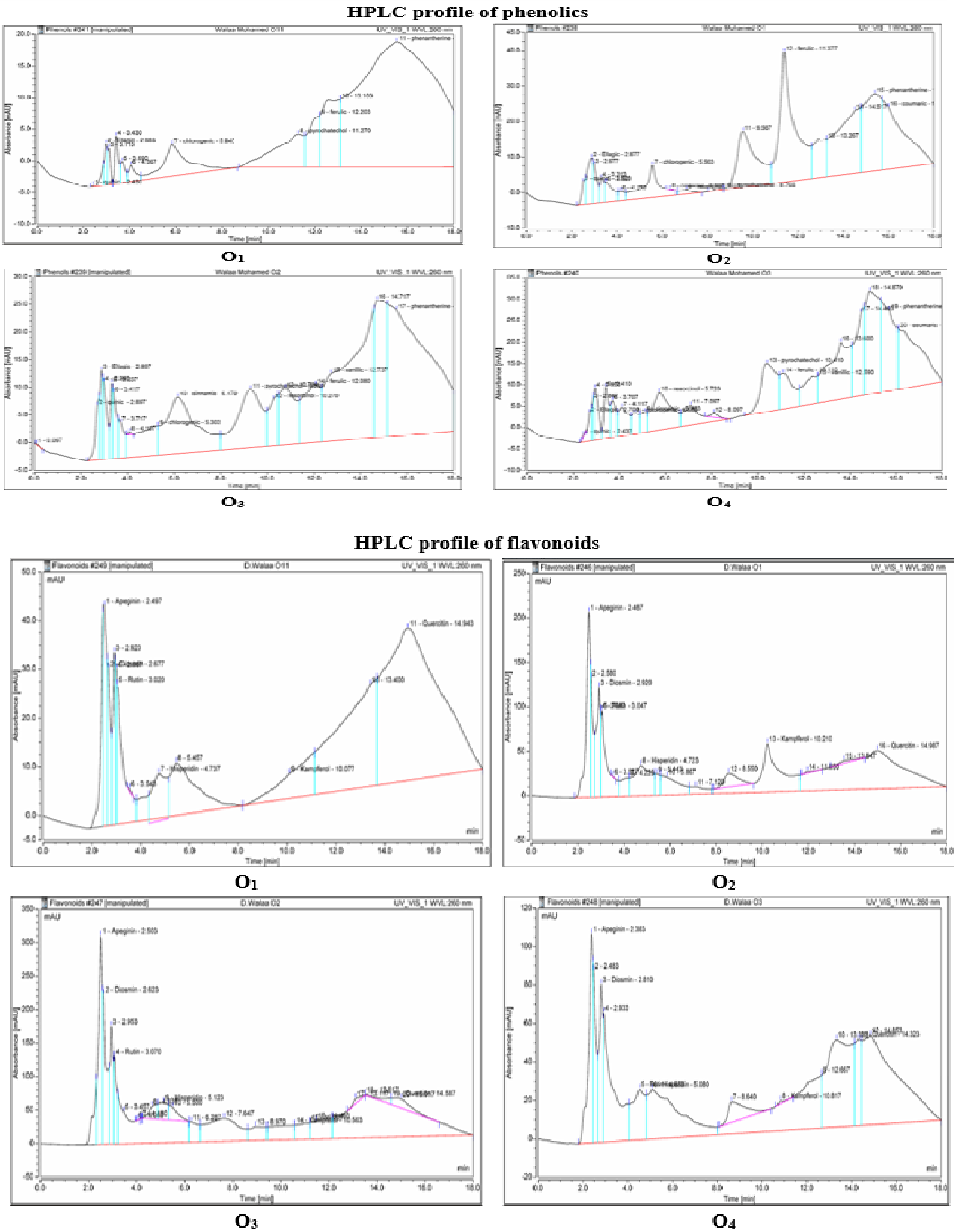

Fig. 1. HPLC profile of phenolics and flavonoids in oats flour and sprouted oatmeal during the sprouting process

Table 3. Amino acid profile of sprouted oatmeal during the sprouting process

Name mg/g	O_1	O_2	O_3	O_4
Essential amino acids				
Histidine	10.62	2.93	5.30	7.04
Valine	31.54	13.06	13.98	8.99
Phenylalanine	13.37	9.31	6.29	7.21
Threonine	6.20	1.68	2.29	2.47
Methionine	0.31	0.17	1.05	1.32
Lysine	16.84	4.72	5.19	7.84
Isoleucine	14.46	7.06	4.35	4.07
Leucine	25.61	14.29	7.38	8.74
Non-essential amino acids				
Arginine	19.03	7.34	8.78	8.77
Proline	9.68	7.37	3.05	7.93
Serine	7.00	5.25	1.63	1.89
Glutamic acid	67.36	49.39	18.24	25.62
Glycine	10.74	6.87	2.96	3.77
Alanine	12.15	7.12	5.79	3.97
Tyrosine	2.48	1.72	1.94	2.18
Aspartic acid	23.68	16.11	8.73	9.26
Cysteine	2.10	-	0.34	0.06

Table 4. Mean value of proximate composition of oat milks produced by sprouted oatmeal during the sprouting process

Components	OM_1	OM_2	OM_3	OM_4	Cow milk*
Total Soluble Solids (T.S.S) (°Brix)	$2.80^c \pm 0.032$	$5.10^b \pm 0.022$	$5.10^b \pm 0.015$	$5.30^a \pm 0.019$	-
Total Fat (%)	$2.48^a \pm 0.025$	$1.10^b \pm 0.012$	$1.09^b \pm 0.017$	$0.70^c \pm 0.020$	3.80
Proteins (%)	$2.50^d \pm 0.014$	$2.68^c \pm 0.012$	$3.06^b \pm 0.011$	$3.10^a \pm 0.015$	3.10
Ash (%)	$0.26^c \pm 0.001$	$0.27^b \pm 0.002$	$0.28^{ab} \pm 0.001$	$0.29^a \pm 0.001$	0.78
Carbohydrates[1] (%)	$2.61^d \pm 0.020$	$2.73^c \pm 0.015$	$2.93^b \pm 0.012$	$3.05^a \pm 0.025$	4.80
Total Phenolics (%)	$0.24^c \pm 0.002$	$0.30^b \pm 0.001$	$0.33^a \pm 0.002$	$0.35^a \pm 0.004$	-
Total Energy (Kcal./100ml)	42.76	31.54	33.77	30.90	65.80

Means ± standard deviation followed by different small letters in the same row (effect of increased sprouted period on sprouted oatmeal compared to oat flour to produce oat milks) are significantly different by Duncan´s multiple test ($p \leq 0.05$).

* Source: Salama *et al.* (2011).

[1] Carbohydrate content was estimated by Chaplin and Kennedy (1994).

The increase in soluble solids and carbohydrates is partly due to the hydrolysis of large molecules of insoluble starch into reducing sugar and soluble dextrin, and the solubilization of proteins and other substances (Zhou, 2024), which occurs as a result of the activity of amylase enzyme during sprouting.

Nevertheless, total fat content decreased from 2.48 to 0.70% and calorie content decreased from 42.76 to 30.90 Kcal. /100ml. The lower calorie content of oat milk with a longer sprouting period is due to the lower fat content, which was consumed during sprouting. These results are consistent with the results of Table (1) above, which shows the effect of sprouting period on the chemical composition of oat grains.

Based on the observed data, it can be seen that oat milk can be considered a good alternative to cow's milk, especially oat milk produced from sprouted oatmeal, because it contains a high percentage of protein, almost comparable to that of cow's milk, as well as a high carbohydrate content. Oat milk, on the other hand, is characterized by its lower fat and, therefore, calorie content compared to cow's milk, making it a great choice for people with a milk allergy.

Data in Table (5) elucidate the mineral content of oat milk produced by oats flour (OM_1) and sprouted oatmeal with increasing sprouting period, which showed significant differences ($p \leq 0.05$) resulting from the concentration of mineral elements (Fe, Ca, Mg, Cu and Mn) with increasing sprouting period.

Table 5. Mineral contents of oat milks produced by sprouted oatmeal during the sprouting process

Treatment	Bio-minerals (ppm)					
	Fe	Ca	Mg	Zn	Cu	Mn
OM_1	$217.50^d \pm 0.5$	$1223.75^d \pm 1.0$	$626.25^d \pm 0.5$	$62.50^a \pm 0.3$	$10.00^c \pm 0.2$	$18.75^d \pm 0.4$
OM_2	$221.25^c \pm 0.05$	$1336.25^c \pm 2.0$	$863.75^c \pm 1.0$	$51.25^b \pm 0.5$	$26.25^c \pm 0.3$	$20.00^c \pm 0.2$
OM_3	$372.50^b \pm 1.5$	$1578.75^b \pm 2.0$	$936.25^b \pm 2.4$	$40.00^c \pm 1.0$	$28.75^b \pm 0.5$	$22.50^b \pm 0.5$
OM_4	$386.25^a \pm 1.0$	$1596.25^a \pm 1.5$	$985.00^a \pm 1.3$	$40.00^c \pm 1.2$	$33.75^a \pm 1.0$	$23.75^a \pm 0.3$

Means ± standard deviation followed by different small letters in the same column (effect of increased sprouted period on sprouted oatmeal compared to oat flour to produce oat milks) are significantly different by Duncan´s multiple test ($p \leq 0.05$).

Results in Table (5) included relative significantly increase ($p \leq 0.05$) in contents of Fe (from 217.5 to 386.25 ppm), Ca (from 1223.75to 1596.25 ppm), Mg (from 626.25 to 985.0 ppm), Cu from (10.0 to 33.75 ppm) and Mn (from 18.75 to 23.75 ppm) in oat milk produced from sprouted oatmeal with an increase in the sprouting period compared to OM_1. Unless Zn (62.50-40.0 ppm) decreased in oat milk produced by oatmeal sprouted with an increased sprouting period compared to OM_1. The same trend as the data in Table (2) and in Table (5), with a slight change in the mineral element values. This indicates that the process of manufacturing oat milk from oat grains and their sprouting oats did not affect the mineral content.

HPLC analysis of flavonoid and phenolic compounds in oat milk produced by oats flour (OM_1) and sprouted oatmeal with increased sprouting period (OM_2, OM_3 and OM_4) were determined, and the results are indicated in Fig. (2). Oat milk produced by sprouted oatmeal reinforce most compounds, producing the highest levels of key flavonoid: apigenin (0.7123 mg/g), quercetin acid (1.2418 mg/g) and hisperidin acid (6.4066 mg/g). Phenolic acids followed a similar trend, with quinic acid increasing 1.2-fold, cinnamic acid (>6-fold) and coumaric acid (>60-fold), aside from the production of individual components, such as pyrochatechol, phenanthrene and ferulic acid in oat milk produced by sprouting compared with oat milk OM_1.

Data elucidated sprouting-induced variations in some phytochemicals. Oats milk produced by oats flour (OM_1) implicated quinic acid (0.0167 mg/g), cinnamic acid (0.0035 mg/g) and coumaric acid (0.0012 mg/g), oats milk produced by sprouted oatmeal increased most phenolics (quinic acid: 0.0194; cinnamic acid: 0.0230 mg/g; coumaric acid: 0.0724 mg/g) and created new compounds such as pyrochatechol acid (0.0011 mg/g), phenanthrene acid (0.0027 mg/g) and ferulic acid (0.0042 mg/g), at the end of the sprouting period.

Additionally, flavonoid compounds levels: hesperidin acid increased 3-fold, apigenin acid (1.2-fold), diosmin acid (1.25-fold) and rutin acid (1.8-fold) in oat milk produced by sprouting compared with oat milk OM_1. These results are consistent with the results of Fig. (1) above, which shows the effect of sprouting period on flavonoids and phenols content of oat grains. Which observed that the industrialization of oat milk processing improved their content compared to oat grains, so increasing their antioxidant capacity and activity.

Amino acid profile in oat milk produced from oat flour (OM_1) and sprouted oatmeal with an increased sprouting period was detected, and data were articulated in Table (6). Results showed that sprouting process improved amino acid profile of oat milk produced with increasing sprouting period, resulting in an increase in almost amino acids including lysine (>3- fold), histidine (>3- fold), valine (>2- fold), arginine (>2- fold), glycine (>2- fold) and alanine (>2- fold), exception methionine, phenylalanine and threonine, which decreasing with increased sprouting period. Distinctive appearance of cysteine during sprouting with an increase of more than two-fold at the end of the sprouting period.

Glutamic acid was the most abundant amino acid in the produced oat milk, with a concentration of 11.52 mg/g, followed by valine at 5.56 mg/g, and aspartic acid at 5.05 mg/g, at the end of the sprouting period. Lysine increased from 0.77 to 2.98 mg/g, histidine (0.71 to 2.28 mg/g), valine (2.69 to 5.56 mg/g), arginine (1.64 to 4.80 mg/g), glycine (1.25 to 3.14 mg/g) and alanine (1.31 to 3.30 mg/g), at the end of the sprouting period.

It can be seen that the trend of the data in Table (6) is contrary to the trend shown in Table (3), most likely because metalloproteinases hydrolyzed oat proteins in soluble form (Kaukovirta-Norja *et al.*, 2004), leading to an increase in the amino acid content of the milk produced with an increase in the sprouting period.

Therefore, it can be noted that oat milk produced from sprouted oatmeal has a higher nutritional value compared to oat milk produced from oat flour (OM_1) due to its high content of amino acids, especially at the end of the sprouting period (OM_4).

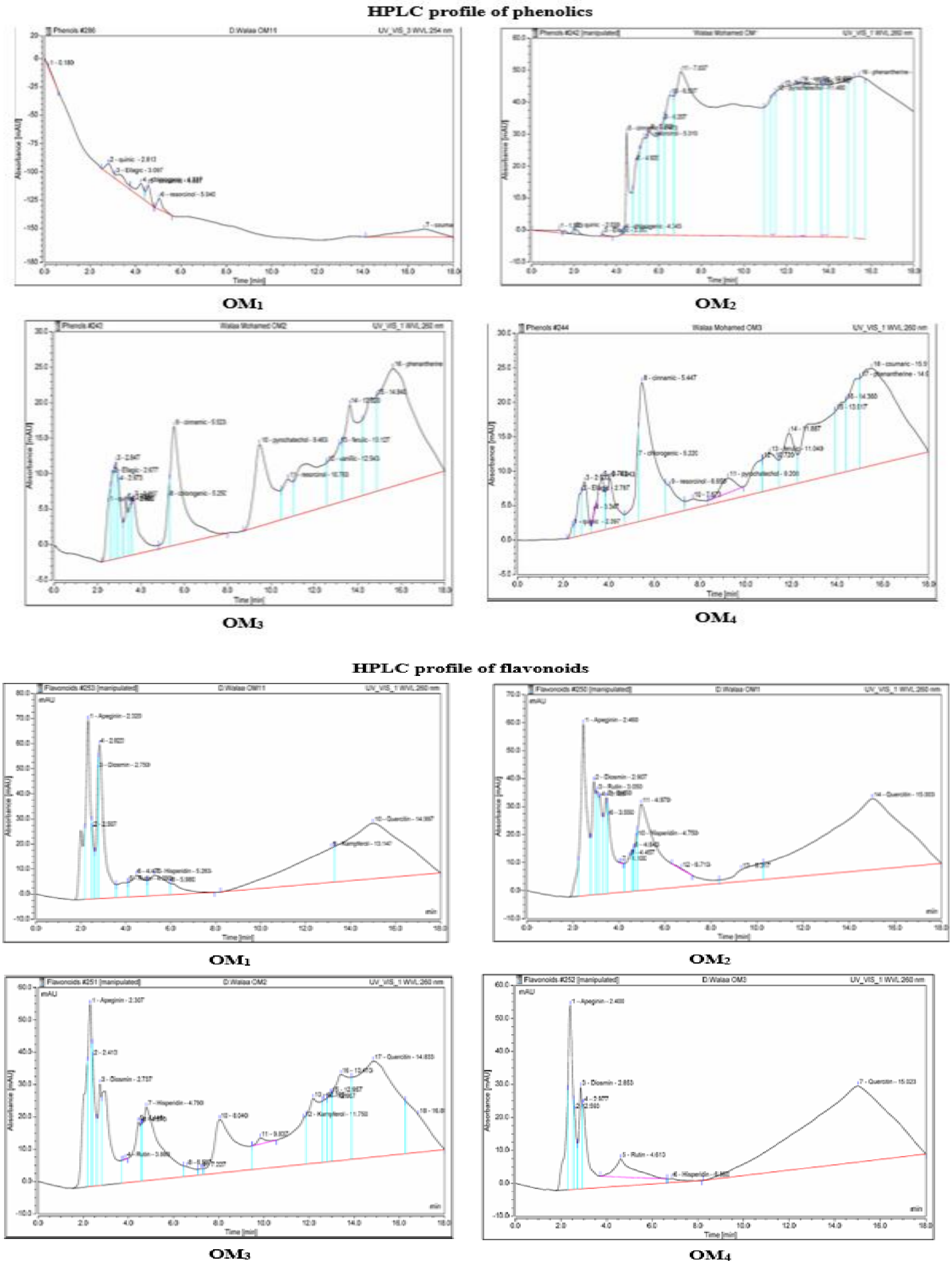

Fig. 2. HPLC profile of phenolics and flavonoids in oat milks produced by oats flour and sprouted oatmeal during the sprouting process

Table 6. Amino acid profile of oat milks produced by sprouted oatmeal during the sprouting process

Name mg/g	OM_1	OM_2	OM_3	OM_4
Essential amino acids				
Histidine	0.71	1.70	0.47	2.28
Valine	2.69	2.30	0.87	5.56
Phenylalanine	3.40	1.38	0.80	2.66
Threonine	0.73	0.38	0.02	1.52
Methionine	0.47	0.14	0.00	0.30
Lysine	0.77	1.38	1.59	2.98
Isoleucine	1.42	0.92	0.40	2.48
Leucine	2.50	2.31	3.01	4.36
Non-essential amino acids				
Arginine	1.64	2.48	3.78	4.80
Proline	1.62	1.20	1.76	1.96
Serine	0.85	0.71	0.02	1.53
Glutamic	8.08	4.69	1.27	11.52
Glycine	1.25	0.77	1.20	3.14
Alanine	1.31	1.96	1.56	3.30
Tyrosine	0.86	1.70	0.24	1.47
Aspartic	3.24	1.67	3.10	5.05
Cysteine	0.00	0.49	0.60	1.06

Table 7. Sensory properties of oat milks produced by sprouted oatmeal during the sprouting process

Sample	OM_1	OM_2	OM_3	OM_4
Taste	$8.50^{b} \pm 0.69$	$8.75^{ab} \pm 0.60$	$9.25^{a} \pm 0.70$	$8.25^{b} \pm 0.75$
Odor	$8.25^{b} \pm 0.50$	$8.75^{ab} \pm 0.70$	$9.15^{a} \pm 0.90$	$8.75^{ab} \pm 0.60$
Color	$9.15^{a} \pm 0.29$	$9.25^{a} \pm 0.40$	$9.00^{a} \pm 0.47$	$8.25^{b} \pm 0.80$
Texture	$9.00^{ab} \pm 0.25$	$9.40^{a} \pm 0.30$	$9.15^{a} \pm 0.\ 20$	$8.25^{b} \pm 0.50$
Overall acceptability	$8.50^{b} \pm 0.65$	$9.25^{a} \pm 0.80$	$9.25^{a} \pm 0.75$	$8.50^{b} \pm 0.48$

Means ± standard deviation followed by different small letters in the same column (effect of increased sprouted period on sprouted oatmeal compared to oat flour to produce oat milks) are significantly different by Duncan´s multiple test ($p \leq 0.05$).

Sensory properties are an important indicator of potential consumer preferences. Sensory properties of oat milk produced from oat flour (OM_1), as a control, were compared with oat milk produced from sprouted oatmeal with an increased sprouting period were evaluated, and the results were presented in Table (7). It can be seen that the properties of oat milk were affected by increasing the sprouting period. Significant differences ($p \leq 0.05$) were observed for all sensory properties amongst oat milk samples.

From the obtained data in Table (7), it could be observed that sample OM_3 had the highest properties compared to all samples, followed by OM_2. Taste and odor were highest in sample OM_3 followed by $OM_{2,}$ then $OM_{4,}$ as compared with OM_1. There were no Significant differences ($p \leq 0.05$) among all samples in terms of color, except for OM_4, which was the lowest of all samples. Overall acceptability of oat milk samples was higher (9.25) for sample OM_2 and OM_3 than for OM_1 and OM_4 (8.50). Generally, the sensory properties of oat milk improved in all samples with increasing sprouting period, except for sample OM_4, which decreased. In particular, oat milk produced from oatmeal sprouted two days after sprouting (OM_3) was more acceptable than oat milk produced from oat flour (OM_1). This is probably due to the increased carbohydrate and protein contents of oat milk, as shown in Table (5), which occurs as a result of the activity of hydrolytic enzymes during sprouting (Zhou, 2024).

CONCLUSION

Given the high nutritional and health value of oats, oat milk can be considered a good alternative to cow's milk, especially oat milk made from oat flour, as it contains a high protein content similar to that of cow's milk. Interestingly, the sprouting process improves the nutritional properties of the oat grains and the milk extracted from them, resulting in higher levels of minerals, antioxidants, and amino acids than oat milk made from oat flour. The sprouting process enhances the antioxidant, sensory, and nutritional properties of oat milk, making it an excellent choice for people with milk allergies and vegetarians. Sprouting is also a simple and inexpensive process compared to using enzymes to produce oat milk.

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الملخص العربي

لبن الشوفان كغذاء وظيفي منتج من حبوب الشوفان المنبته

ولاء محمد أحمد السيد

أُجريت هذه الدراسة لتقييم تأثير فترة الإنبات على القيمة الغذائية (التركيب الكيميائي التقريبي، ومحتوى المعادن الحيوية، والأحماض الأمينية، والمكونات النشطة بيولوجيًا (الفينولات والفلافونويدات)) لحبوب الشوفان ولبنها المُنتَج منها. أدت عملية الإنبات إلى تحسين القيمة التغذوية لحبوب الشوفان مع زيادة فترة الإنبات. من ناحية أخرى، اتبع لبن الشوفان المُنتَج من دقيق الشوفان المُنبتَ نفس اتجاه حبوب الشوفان المُنبتَه. أما بالنسبة لمحتوى المعادن، فقد أظهر اتجاهًا متزايدًا خلال عملية الإنبات، وكذلك في لبن الشوفان المُنتَج من الحبوب المُنبتَه، كما يلي: الحديد (١,٨ ضعف)، والكالسيوم (١,٣ ضعف)، والمغنيسيوم (١,٦ ضعف)، والنحاس (٣,٤ ضعف)، والمنجنيز (١,٣ ضعف). أظهر تحليل كروماتوغرافيا السائل عالي الأداء (HPLC) أن عملية الإنبات عززت المكونات الفينولية والفلافونويدية، مثل الكينيك، والسيناميك، والأبيجينين، والديوسمين، والروتين، والكومارين، والبيروكاتيكول، والفينانثرين، وحمض الفيروليك. ولوحظ تحسن في الخصائص الحسية وقبول لبن الشوفان المُنتَج من دقيق الشوفان المُنبت. ويُمكن القول إن الإنبات عملية بسيطة وغير مكلفة، إلا أنها تٌعزز القيمة التغذوية ومضادات الأكسدة والخصائص الحسية للبن الشوفان، مما يجعله خيارًا ممتازًا لمن يعانون من حساسية الحليب والنباتيين.

الكلمات الدلالة: الأغذية الوظيفية، لبن الشوفان، عملية الإنبات، القيمة الغذائية، المركبات الفينولية والفلافونويدية.