Research Article

Journal of Nutrition and Food Science Research

A highly antioxidant functional apple-based juice fortified with aqueous extract of freeze-dried Moringa oleifera leaves: study of physicochemical, nutritional and sensory properties

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Received Date: April 11, 2024
Accepted Date: April 12, 2024
Published Date: May 12, 2024

ABSTRACT

Developing foods with boosted functionality to minimize the potential side effects of oxidative/nitrosative stress and support the immune system while responding to consumers' needs and preferences is a challenging trend in the food industry. The use of Moringa oleifera leaves, characterized by their high nutritional value and multiple pharmacological properties, is emerging in food applications. The present study aimed at developing a functional ready-to-serve apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves (A.F.D.MO), studying the antioxidant, physicochemical, and nutritional properties, estimating the sensory shelf-life for 14 days, and evaluating the consumer acceptance. Apple juice, aqueous extract of freeze-dried Moringa oleifera, orange juice, and lemon juice were added in the following proportions (58:20:20:2) and pasteurized at 90 °C for 30 seconds. The newly developed fruit blend appeared to have a pH of 3.5 and total soluble solids of 10%, with a high antioxidant activity at 1 mg/ml concentration and recorded to be 90.4%. A.F.D.MO was found to be microbiologically safe and retained its sensory attributes during 14-day storage at refrigeration and even at ambient temperature. The sensory evaluation of the apple-based juice fortified with 20 % aqueous extract of freeze-dried Moringa oleifera leaves portrayed a highly accepted fruit juice blend by potential Lebanese consumers owing to its taste. Freeze-dried Moringa oleifera leaf extract was found to be a suitable natural preservative and a functional component with health-promoting properties that could support the body's immune system.

Keywords : Freeze-dried Moringa oleifera leaves, Apple-based juice, Immune system, Functional foods, Antioxidant activity

INTRODUCTION

Consumers' concerns about health and disease prevention with interest in improving the quality of their diet motivated the scientific community to focus on developing functional foods as sources of nutrients and bioactive components with antioxidant properties (Baker et al., 2022). Antioxidants can mitigate oxidative/nitrosative stress and its consequences. Oxidative/nitrosative stress is reported to deteriorate cells and tissues and contribute to the pathogenesis of many metabolic and inflammatory diseases. Antioxidants can be endogenous, produced in the body as enzymes or non-enzymatic compounds. They can also be exogenously supplied from food or as dietary supplements and preservatives. It is

well-documented that exogenous antioxidants can support the body's endogenous antioxidative defense (Pisoschi et al., 2021). Moreover, a growing body of evidence confirms that nutrients with antioxidant properties are vital for an optimal immune system (Gombart et al., 2020; Khadim & Al-Fartusie, 2021). Recent concerns about the side effects of synthetic antioxidants conjointly with the rising prevalence of infectious and non-communicable diseases have shifted the attention towards medicinal plants possessing functional bioactive components with antioxidant and immunomodulation properties (Ayoka et al., 2022; Khadim & Al-Fartusie, 2021).

Moringa oleifera (MO) is among the medicinal plants that gained attention. Their leaves became a research interest worldwide due to their high nutritional value, bioactive substances, multiple pharmacological properties, and immunomodulatory characteristics (Kashyap et al., 2022; Mehwish et al., 2022). MO leaves appeared to be a valuable source of macro and micronutrients. They are high in digestible protein encompassing ten essential amino acids (Kashyap et al., 2022; Rathnayake et al., 2019). MO leaves comprise sulfur-containing amino acids, namely methionine and cystine, which are reported as powerful antioxidants (Rathnayake et al., 2019). The leaves contain fatty acids with appreciable quantities of omega-3. They appeared to be rich sources of minerals and vitamins with antioxidant activity (El-zainy et al., 2017; Kashyap et al., 2022; Rathnayake et al., 2019). Recent studies on MO leaves have elucidated that they contain phenolic compounds, carotenoids, alkaloids, glucosinolates, isothiocyanates, and other bioactive substances. These nutritional and functional properties encourage the exploration of MO leaves in food applications (Hassan et al., 2021; Kashyap et al., 2022; Rathnayake et al., 2019). It was found that freeze-drying is the best method of preserving the phytoconstituents and biological properties of MO leaves (Ademiluyi et al., 2018). To the best of the authors' knowledge, the use of freeze-dried MO leaves in food applications was not extensively studied. Therefore, studying their use as value-added ingredients in food products that satisfy consumers' expectations is imperative.

Fruit juices are among the active functional food categories due to their sensory properties and nutritional value. Apple juice is one of the most popular products in the world in terms of production and international exchange. Apple juice is considered an ideal fortification candidate, distinguished in flavor and intermediate in bioactive compounds (Grobelna et al., 2019; Nour, 2022). Fresh orange and lemon juices are good sources of bioavailable antioxidant compounds (Miles & Calder, 2021; Zou et al., 2016). Citrus juices contain odor-active volatile compounds. Therefore they were selected as ingredients that contribute to the flavor profile of the functional juice (Wang et al., 2020).

The present study aimed (1) to develop a functional ready-to-serve apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves (A.F.D.MO), (2) study its antioxidant activity, physicochemical, and nutritional properties, (3) assess its sensory shelf-life for 14 days, (4) and evaluate the consumer acceptance.

MATERIALS AND METHODS

Materials Procurement

The varieties of fruits were purchased from the local Lebanese market. The apples (Malus domestica) "Red Delicious", oranges (Citrus sinensis) "Valencia", and lemons (Citrus limon) were of premium quality, matured, and freshly harvested. MO leaves were obtained as organic, freeze-dried, and vacuum packed imported from India via "Dr. Moringa company, Beirut, Lebanon."

Juices Preparation

Apple juice

Apples were sorted, washed thoroughly, cut into quarters, and submerged in distilled water containing 30 ml of orange and 30 ml of lemon juices. The apple cuts were then blanched at 75^{O}C, drained, and ground into small pieces using an electrical food processor (Magimix MX5200B Cuisine System XL Food Processor). The apple sauce obtained was placed in a muslin cloth and cold pressed using a hydraulic press juicer extractor machine to get apple juice without pulp.

Citrus juices

The citrus fruits were sorted, washed thoroughly, cut into halves, and squeezed using an electrical juicer (Bifinett KH 85 Citropress, Germany). The juices obtained were filtered using a sterilized cheesecloth.

MO extract

The freeze-dried MO leaves were homogenized to a fine powder using an electric grinder (Moulinex electric coffee grinder). The aqueous extract was obtained following the method applied by El-Zainy et al. (El-zainy et al., 2017). 4g of MO powder was infused with 50 ml of boiling water at 100^{O}C for 5 minutes, then filtered via sterilized muslin cloth to obtain a filtrate.

All juices and MO aqueous extracts were freshly prepared and mixed immediately at different proportions.

Apple-based juice with aqueous extract of freeze-dried MO leaves juice

The A.F.D.MO was obtained by mixing apple juice, MO extract, orange juice, and lemon juice in the following proportion (58:20:20:2). The mixture obtained was placed in sanitized closed glass bottles and pasteurized in a water bath at 90^{O}C for 30 seconds. Samples of the A.F.D.MO were stored at two

different temperature conditions: refrigeration temperature of 4°C (RT) and ambient temperature fixed at 25°C (AT) away from light.

Physicochemical properties analysis

The physiochemical analysis of the apple, orange, and lemon juices and A.F.D.MO was performed on the production day (T0). The pH was recorded with a digital pH meter, and the total soluble solids (TSS) content was determined using a digital refractometer. TSS was measured as a percentage (% TSS) (Horwitz, 2010). The results were expressed as the mean value ± standard deviation of three separate determinations.

Antioxidant activity determination

The antioxidant activity of the A.F.D.MO and Vitamin C as a control were measured by the DPPH free radical-scavenging activity assay following a previously reported method with minor modifications (Hashemi et al., 2018). In brief, 2 g of the A.F.D.MO with 60 ml methanol was extracted by 1% HCL at room temperature for 1 hour. The extract was centrifuged at 2500 RPM for 15 minutes at 25°C. The upper layer was collected. The pH of the collected extract was adjusted to reach 3. Various concentrations of the solution to be tested were mixed with 1 ml of 0.6 mM DPPH methanolic solution. The mixtures and the blank (6.3 mg in 100 ml methanol) were vortexed and left in the dark for 30 minutes. Then, the absorbance for each sample concentration was read at a wavelength of 517 nm using a spectrophotometer. The calculated results were recorded as percentage inhibition of DPPH using the following formula (Nobosse et al., 2017).

% inhibition=((A control-A sample))/(A control)* 100

"A control" stands for the absorbance of the control (DPPH solution without sample), whereas "A sample" stands for the absorbance of the sample (DPPH solution with sample). The antioxidant activity of the extract was compared to the antioxidant activity of Vitamin C, a potent antioxidant. The results were expressed as the mean value ± standard deviation of three separate determinations.

Microbiological examination

The microbiological analysis of A.F.D.MO was performed three times on the production day (T0). Aerobic colony count was tested after aerobic incubation at 30°C based on the reference method ISO 4833-1:2013. Enumeration of E. coli and total coliforms was carried out on a chromogenic medium after incubation for 24 h at 44°C and 37°C, respectively according to the reference method AOAC-RI # 050601. Glucose agar with yeast extract and chloramphenicol (YGC) was used for the enumeration of yeasts and molds after incubation at 25°C (ISO 7954). Results were expressed as colony-forming units (CFU/ml). The presence of Salmonella was also tested on production day (T0) based on the rapid detection method V.I.D.A.S. enzyme-linked fluorescent immunoassay (AOAC-RI #071101).

Sensory shelf-life estimation

A sensory shelf-life estimation was performed based on a previously reported method with slight modifications (Obasi et al., 2017). The sensory shelf-life estimation of the A.F.D.MO samples stored at a refrigeration temperature of 4°C (RT) and ambient temperature fixed at 25°C (AT) was conducted to evaluate any change in the sensory attributes during a 14-day storage. The panelists (n=3) were trained researchers from the Department of Nutrition and Dietetics, Faculty of Public Health, Lebanese University, aged between 25 and 45 years, with no stated history of disorders that might affect oral perception. Following the approval of the Ethics Committee at the Doctoral School of Science and Technology (DSST), written consent was taken. Each panelist evaluated the A.F.D.MO samples on production day (T0) and day 3 (T3), day 6 (T6), day 9 (T9), and day 14 (T14) for the taste, odor, color, texture, and overall acceptability, based on a five-point structured hedonic scale (1-dislike extremely, 2-dislike moderately, 3-neither like nor dislike, 4-like moderately, and 5-like extremely). Water was used as a palate cleanser (Hashemi et al., 2018).

Consumer acceptance evaluation

A sensory evaluation was carried out by untrained potential consumers to assess the acceptance of A.F.D.MO in terms of organoleptic quality. The sensory evaluation was approved by the Ethics Committee at the DSST and was performed on day 1 after production in a sensory laboratory at the Chamber of Commerce, Industry, and Agriculture of Tripoli. Forty-six participants aged between 18 and 65 years old (30 females and 16 males) were recruited through an invitation message shared via "WhatsApp." The sensory evaluation was performed under optimal conditions (temperature: 25°C, humidity: 53%). Participants were introduced to the evaluation method and signed a consent form before participation. They were blind to the food product. They were seated in individual testing booths with proper illumination and away from any distractions. Water was used as a palate cleanser before tasting the juice sample (Lawless & Heymann, 2010). Participants were offered 25 ml of A.F.D.MO in transparent white glass cups for proper assessment. They were asked to evaluate five sensory attributes: taste, odor, color, texture, and overall acceptability, based on a five-point structured hedonic scale with 1-dislike extremely, and 5-like extremely (Hashemi et al., 2018).

Nutrition facts

The nutrient composition of A.F.D.MO was calculated using

Genesis R & D Food Labeling Software (ESHA Research, Salem, OR, USA) (Gourineni et al., 2020). The amounts of each ingredient in grams were incorporated into the software, which already has the nutritional information of each one. The nutritional facts were calculated based on the serving weighing 100 g in the current study.

Statistical analysis

The results were analyzed using Excel and SPSS (I.B.M. Statistics version 23). Antioxidant activity results are expressed as mean values ± standard deviation where an independent samples t-test was used to determine the significance among mean values. Sensory parameters results are expressed as mean values ± standard deviation where a one-way ANOVA followed by Tukey's post hoc test was used to determine the significance among different groups. All differences were considered significant for p-value ≤0.05. The Pearson correlation coefficient between descriptors was assessed. The correlation was considered significant at the 0.01 level (2-tailed).

RESULTS AND DISCUSSION

Physicochemical properties

The results of the physicochemical parameters are given in Table 1. The pH of the apple, orange, and lemon juices, as well as the A.F.D.MO were 3.9, 4.3, 2.2, and 3.5 respectively.

The pH is one of the important physicochemical characteristics that influence the quality and the bioactive compounds' stability of fruit juices (Grobelna et al., 2019). The A.F.D.MO is a high-acid juice, having a pH of 3.5. This acidity could be attributed to the citrus juices added and to the submersion of apple cuts in the lemon/orange juices in the preparation phase. Both lemon and orange juices are classified as high-acid juices (Ağçam et al., 2018). Noteworthy, is that the pH of the aqueous extract of dry MO leaves was reported to be 7.07 (El-zainy et al., 2017). The acidity of A.F.D.MO appears to agree with the orange juice treated with 20 % MO leaf extract and 10% ginger extract recorded to have a pH of leaves extract 3.6 (Hashemi et al., 2018).

The % TSS of the apple, orange, and lemon juices, as well as A.F.D.MO were 11%, 12%, 8%, and 10 % respectively. The TSS value is a quality-control criterion used in the juice industry, reflecting the release of soluble compounds due to tissue destruction resulting from juice preparation procedures. The TSS results of A.F.D.MO is recorded to be lower in comparison to the orange juice treated with 20 % MO leaves extract and 10% ginger extract which could be attributed to the reduced concentration of solids dissolved in the juice (Hashemi et al., 2018).

Table 1 : The pH and total soluble solids of apple juice, orange juice, lemon juice, and A.F.D.MO.

Physicochemical characteristics at T0	Apple Juice	Orange Juice	Lemon Juice	A.F.D.MO
pH	3.9 ± 0.02	4.3 ± 0.03	2.2 ± 0.02	3.5 ± 0.02
Total soluble solids %	11 ± 0.00	12 ± 0.01	8 ± 0.00	10 ± 0.03

The values represent means ± standard deviation

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

Antioxidant activity

The DPPH free radical scavenging activity of A.F.D.MO at different concentration levels was significantly lower than Vitamin C (p-value ≤0.05) (Table 2). Although, a statistical difference was observed between the antioxidant activity of A.F.D.MO at a concentration of 1 mg /ml (90.4 ± 0.31%) and that of control Vitamin C extract (100 ± 0.00 %) (p-value ≤0.05); however, it was noted that A.F.D.MO is considered to have a high antioxidant property. The DPPH scavenging capacity of A.F.D.MO was shown to be superior to the scavenging capacity reported previously of pasteurized apple (24.95 %), orange (58.90%), and lemon (81.53%) juices (Benattouche et al., 2021; Li et al., 2018; Uçan et al., 2016). A.F.D.MO presented a higher DPPH scavenging capacity than the orange juice mixture prepared by Hashemi et al., which was recorded as 72.68% (Hashemi et al., 2018). Although 20 % MO leaf extract was used in both studies, the MO leaves in the current were freeze-dried, whereas in the Hashemi et al. study, they were hot-dried. The high antioxidant activity of A.F.D.MO could be due to the joint action of bioactive compounds; vitamin C, phenols, and flavonoids (Chlorogenic acid, caffeic acid, and rutin) already detected in the freeze-dried MO leaves (Ademiluyi et al., 2018; Zou et al., 2016). The synergistic effect of bioactive compounds co-delivered by the freeze-dried MO leaves and the citrus juices could explain the further enhancement of the A.F.D.MO antioxidant activity (Vichaibun

& Kanchanaphu, 2019). The current study's findings support the use of freeze-dried MO leaves to enhance the functionality of food products.

Table 2 : DPPH free radical scavenging activity of A.F.D.MO as compared to Vitamin C

Volume of extract in test tube	DPPH Inhibition % A.F.D.MO	DPPH Inhibition % Vitamin C
250 µl	58.6 ± 0.10 a	97 ± 0.35 b
500 µl	72 ± 0.14 a	96.7 ± 0.11 b
750 µl	80.4 ± 0.20 a	98 ± 0.47 b
1000 µl	90.4 ± 0.31 a	100 ± 0.00 b

µl: microliter; %: percentage. The values represent means ± standard deviation. Means in the same row not sharing the same alphabetical letter are significantly different (p-value ≤0.05)

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

Microbiological analysis

The microbiological results are presented in Table 3. According to L.I.B.N.O.R. standards, bacteria, yeasts, and molds were within the acceptable limit. Salmonella species tested on the production day (T0) were not detected. A.F.D.MO was found to be microbiologically safe.

Table 3 : Microbiological analysis of the A.F.D.MO at production day (T0)

Microorganisms tested at T0	Result	Acceptable limit according to L.I.B.N.O.R.
Aerobic colony count at 30°C	1CFU /ml	5.103 -104
Total coliforms at 37°C	<1 CFU/ml	10-100
Yeast and Molds count at 25°C	<10 CFU /ml	102 -103
E. coli at 44°C	< 1CFU/ml	<10
Salmonella at 41.5°C	Not detected	Absence

CFU: colony forming unit.; ml: milliliter;

L.I.B.N.O.R.: Lebanese Standards Institution

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

Sensory shelf-life estimation

The changes in the sensory attribute scores (taste, odor, color, texture, and overall acceptability) evaluated at 4°C for 14 days are presented in Table 4. Taste and odor received the highest score (5) relative to other parameters from T0 to T14. As for color, a significant change occurred at T3 after production. Nevertheless, the alteration in the texture and overall acceptability was not significant during the 14 days.

Results of the changes in the sensory attributes at ambient temperature (25°C) for 14 days are shown in Table 5. The odor retained a high score (5) for 14 days after production, whereas changes in taste between T6 and T9, in color between T0 and T6, and in overall acceptability between T3 and T9 were significant.

The overall acceptability scores of the A.F.D.MO at T14 was recorded to be 4.66 at 4°C and 4 at 25°C, reflecting that the newly developed fruit blend maintaining its sensory attributes for 14 days. The aqueous extract of freeze-dried MO leaves could have contributed to retaining the sensory quality of A.F.D.MO throughout the storage period at the refrigeration temperature as well as at the ambient temperature. MO leaf extract was reported to have antibacterial and antifungal activities due to its phytochemicals with antimicrobial properties, including tannins, phenolic compounds, and flavonoids (Ahmed et al., 2023). The role of MO leaf extract as a natural preservative in juices has been confirmed previously (El-zainy et al., 2017; Hashemi et al., 2018). In addition, A.F.D.MO was prepared under good manufacturing practices, preserved in sanitized bottles, and pasteurized at 90°C for 30 seconds. Pasteurization is used to inactivate heat-sensitive spoilage and food poisoning microorganisms, such as vegetative bacteria, molds, and yeasts, and to reduce the activity of some enzymes such as pectin esterase, pectin

methyl esterase (Ağçam et al., 2018). The current study's findings also support the use of freeze-dried MO leaves as a natural preservative in the food industry.

Table 4 : Organoleptic properties of A.F.D.MO during storage at a refrigeration temperature of 4°C (RT) from the day of production (T0) up to 14 days after production (T14)

Organoleptic properties	Storage Period (days)				
	T0	T3	T6	T9	T14
Taste	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a
Odor	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a
Color	5.00 ± 0.00 b	4.00 ± 0.00 a	4.00 ± 0.00 a	4.00 ± 0.00 a	4.00 ± 0.00 a
Texture	4.00 ± 0.00 a	3.66 ± 0.57 a	3.66 ± 0.57 a	3.66 ± 0.57 a	3.66 ± 0.57 a
Overall Acceptability	4.66 ± 0.57 a	4.66 ± 0.57 a	4.66 ± 0.57 a	4.33 ± 0.57 a	4.66 ± 0.57 a

The values represent means ± standard deviation for each organoleptic property at different times. Means in the same row not sharing the same alphabetical letter are significantly different (p-value ≤0.05)

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

Table 5 : Organoleptic properties of A.F.D.MO during storage at ambient temperature of 25°C (AT) from the day of production (T0) up to 14 days after production (T14)

Organoleptic properties	Storage Period (days)				
	T0	T3	T6	T9	T14
Taste	5.00 ± 0.00 b	5.00 ± 0.00 b	5.00 ± 0.00 b	4.00 ± 0.00 a	4.00 ± 0.00 a
Odor	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a	5.00 ± 0.00 a
Color	5.00 ± 0.00 b	4.33 ± 0.57 ab	4.00 ± 0.00 a	4.00 ± 0.00 a	4.00 ± 0.00 a
Texture	4.00 ± 0.00 a	3.66 ± 0.57 a	3.66 ± 0.57 a	3.66 ± 0.57 a	3.66 ± 0.57 a
Overall Acceptability	5.00 ± 0.00 b	5.00 ± 0.00 b	4.33 ± 0.57 ab	4.33 ± 0.57 a	4.00 ± 0.00 a

The values represent means ± standard deviation for each organoleptic property at different times. Means in the same row not sharing the same alphabetical letter are significantly different (p-value ≤0.05)

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

Consumer acceptance

The results of the sensory evaluation reflect the acceptance of A.F.D.MO in terms of the sensory attributes (taste, odor, color, texture, and overall acceptability) are presented in Figure 1. The mean values of the five attributes' scores based on the five-point hedonic scale ranged between 4.3 for the odor, 4.48 for the taste and overall acceptability, 4.5 for the texture, and 4.59 for the color. The results show also that 96% of the participants proclaimed the overall acceptability of the product (Figure 2). The correlation between the overall acceptability and the other sensory attributes (color, odor, taste, and texture) revealed that the taste was the attribute having the highest correlation with the overall acceptability (r=0.794) compared to the others, with the texture having a weak correlation (r=0.387) (Table 6). Developing new food products with high-quality characteristics while responding to the consumers' needs and preferences is a challenging trend in the food industry (Pinto, Vilela, and Cosme 2022). Therefore, the sensory quality of the newly developed fruit blend plays a vital role in consumer satisfaction. Findings of the sensory evaluation revealed that A.F.D.MO is found to be a well-accepted natural functional fruit juice blend that could be released in the Lebanese market for health-conscious consumers. The overall acceptability of A.F.D.MO appeared to be higher than the blend prepared by Hashemi et al. (Hashemi et al., 2018).

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Table 6 : Correlation between the overall acceptability and the sensory attributes of A.F.D.MO

	Color	Odor	Taste	Texture
Overall Acceptability	.463**	.433**	.794**	.387**

**Correlation is significant at the 0.01 level(2-tailed)

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

Figure 1

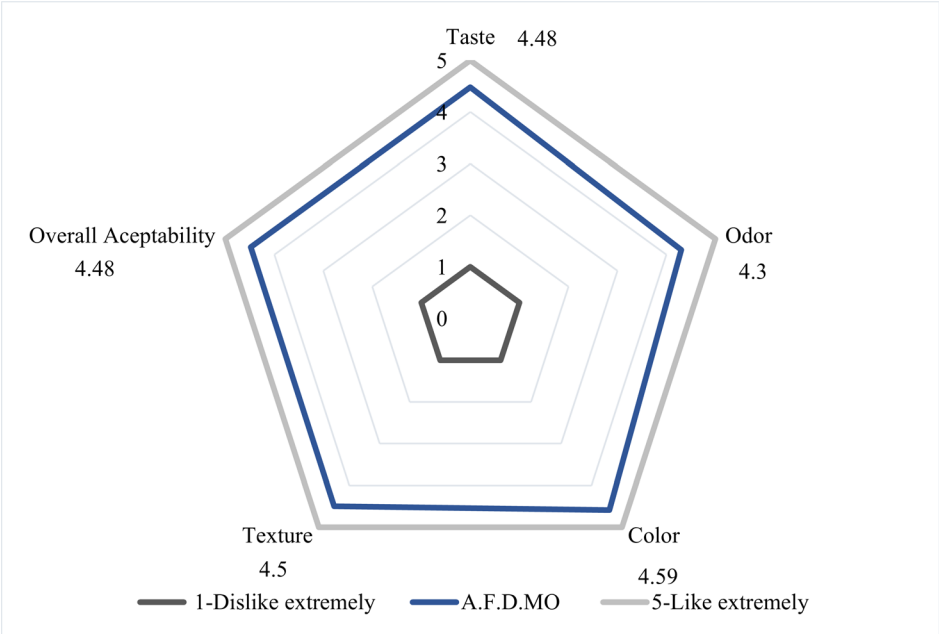

Figure 1 : Hedonic analysis of A.F.D.MO

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

Figure 2 :

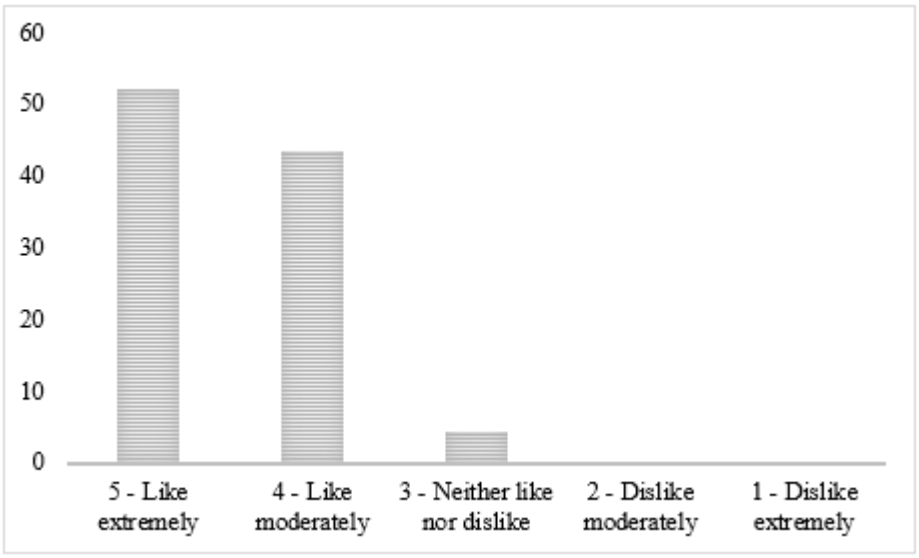

Figure 2 : Overall acceptability of A.F.D.MO by the consumers

Nutrition facts

The nutrient composition of A.F.D.MO presented in Table 7 reveals that 100 g of the apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves yields 45 calories and contains around 11 g carbohydrates, negligible proteins, and fat content, with no trans-fat, or added sugar. Even though nutrients with potential antioxidant properties, such as vitamin E and β-carotene were detected in small amounts, A.F.D.MO appeared to contain a good amount of vitamin C (15 mg/100g) owing to the aqueous extract of MO leaves and the citrus juices (El-zainy et al., 2017; Miles & Calder, 2021). Vitamin C is documented to be one of the micronutrients with solid evidence for supporting the immune system (Gombart et al., 2020).

Table 7 : Nutrient composition of A.F.D.MO

Per 100 g	A.F.D.MO
Calories (Kcal)	45
Total fat (g)	0.18
Saturated fat (g)	0
Trans Fat (g)	0
Cholesterol (g)	0
Sodium (mg)	3.32
Total carbohydrates (g)	10.86
Dietary fibers (g)	0.26
Total Sugar (g)	9
Added Sugar (g)	0
Protein (g)	0.31
Vitamin C- Ascorbic acid (mg/100g)	15
Vitamin E – Alpha Tocopherol Acetate (mg/100g)	0.55
Carotenoids as β-carotene (mcg/100g)	8.11

A.F.D.MO: Apple-based juice fortified with an aqueous extract of freeze-dried Moringa oleifera leaves

CONCLUSION

The current study revealed that apple-based juice fortified with a 20 % aqueous extract of freeze-dried Moringa oleifera leaves is a very accepted functional fruit juice blend characterized by high antioxidant activity and sensory shelf-life stability for 14 days at refrigeration as well as ambient temperature. Freeze-dried Moringa oleifera leaf extract was found to be a suitable natural preservative and a functional component with health-promoting properties that could play a role in supporting the body's immune system.

AUTHORSHIP CONTRIBUTION STATEMENT

Sahar Dandachy : Conceptualization; Investigation; Methodology; Formal analysis; Writing—review and editing; Visualization; Validation.

Amira Fattal : Conceptualization; Investigation; Methodology; Formal analysis; Writing—original draft; Visualization.

Hiba Mawlawi : Project administration; Supervision; Writing—review and editing; Validation.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of the Chamber of Commerce, Industry, and Agriculture of Tripoli. The authors express their gratitude to the volunteer tasters.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

FUNDING

No funding was received for the current study.

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