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FORTIFICATION EFFECT OF *MORINGA OLEIFERA* LEAVES POWDER ON NUTRITIONAL AND VOLATILE COMPOUNDS OF SWEET WHEY BEVERAGE

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ABSTRACT

This study aimed to investigate the fortification of moringa*Oleifera*leaves powder (MOLP) on the nutritional and volatile compounds of sweet whey beverage (SWB).MOLPwas added to sweet whey beverage at three levels 5, 10 and 15%. Fortification with MOLP showed an increase in nutritional value of all blends. Sensory evaluation showed that blend T_1 (5% MOLP) compared favorably with the other blends. The overall acceptability of the beverage was maximum at T_1, therefore this blend had selected for evaluation of volatile compounds using gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS). A total of 26 volatiles were identified in SWB and selected fortification blend at 5%, including 7 aldehydes, 5 alcohols, 11 acids and 3 esters. The most abundant identified volatile compounds were acids followed by aldehydes.

Key words: *Moringaoleifera,* whey beverages, phytochemical, volatile

INTRODUCTION

Whey is the by-product of milk remaining after milk coagulation and removal of the curd and has several commercial uses.World production of whey is approximately 120 X 10^6 tons per annum and the major whey producers were the EU and the US (**FAO, 1999; Kevin, 2012).** Approximately whey contain 93% water and 0.6% protein (**Huffman 1996**), and contains almost 50% of all solids present in whole milk (**Chandan*et al*., 1982**), of which lactose is the main constituent (**Huffman 1996**).It is the most potent pollutant of all thedairy wastes and possess higher amount of organic matter(6-7%) comprising of fat, protein, sugar, minerals andwater-soluble vitamins. It disposed of in rivers, lakes, or other water bodies, treated in wastewater plants, or loaded onto the land**.** This fact represents a significant loss of resources and causes serious pollution problems since whey is a heavy organic pollutant with a high biochemical oxygen demand of 40-60 X 10^3 ppm and a chemical oxygen demand of 50-80 X 10^3 ppm **(Ben-Hassan and Ghaly, 1994).** To some people, whey is a waste, but to others it represents an opportunity for new food development (**Kosikowski and Mistry, 1997)**.

Regulations for preventing disposal of untreated whey and recognition of the value of whey components accelerated in the late 20^{th} century; this resulted in a better understanding of the composition and functional properties of whey (**Anonymous, 2008**). Several technological and biotechnological processes have been proposed for the exploitation of whey during the past years. The list of products obtained is quite long and includes ethanol, lactic acid, single-cell protein, methane, organic acids, proteases, nisin, and oligosaccharides **(Santoro *et al.,* 1999; Pinheiro*et al*., 2000; Fitzpatrick *et al*., 2001; Romero *et al*., 2001)** but these are not economically feasible for smaller dairies. Hence, the diversion of whey solids into the human food chain employing cost-effective technologies appears to be the best alternative to utilize whey. Thus,

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utilization of whey in the manufacture of beverages through fermentation or without fermentation appears to be the most obvious and logical avenue for returning the nutrients into the human food chain (**Yadav *et al*., 2010)**. Conversion of whey into a beverage on a commercial scale also has an economic advantage, as the whole quantity is being used and there are no problems of leftover residues (**Shendurse*et al*., 2009**).

Moringaoleifera known as "miracle tree"is grown in tropical and subtropical countries and is well known for its health benefits. Leaves, flowers and the fruits are being used in traditional food preparations. Its leaves are rich in nutrients and contain significant amounts of minerals and vitamins (**Oluduro, 2012; MisraandMisra, 2014).** It has been reported to be a rich source of protein, vitamins, β-carotene, aminoacids, various phenolics and essential minerals like calcium and potassium (**Toba *et al*., 2010).** Also, nutraceutical and pharmaceuticals beneficial properties including antitumoural, antioxidant, anti-inflammatory/diuretic, antihepatotoxic properties, hypotensive, hypocholesterolemic and hypoglycemic actions (**Sreelatha and Padma, 2010).**In developing countries like Egypt, herbal medicines play an important role in primary health care, especially where coverage of health care service is limited. The nutritional and medicinal information about *M. oleifera* leaves is much available in the literature, but there is rare information about volatile components. Therefore, the aim of the present study is to investigate the effect of *Moringaoleifera*leaves powder fortification on the nutritional quality and volatile compounds of sweet whey beverage.

Materials and Methods

Materials

The sweet whey was obtained from Domtty factory in 6 October, Giza, Egypt. Moringaoleifera leaves was obtained from El-nada farm. Egypt Alex desert road. Abo-ghaleb.

Experimental procedures

Plant collection and preparation of Moringaoleifera leaves powder

The leaves were washed under running tap water and air dried for 8 days under shade. With the aid of grinder, the leaves were grinding into fine powder and stored in airtight glassas as described by **Mensah *et al.* (2012).**

Preparation of sweet whey beverages

10 g of the leaves powder were weighed and poured into 500ml conical flask in which 100ml water was added. The mixture was kept for 12 hrs with constant agitation using a mechanical shaker at 30minuts intervals. The extract was filtered using Whatman number 1 filter paper.The extract obtained was stored in refrigerator for use **(Madukа*et al*., 2014).**

For the preparation of 100ml of herbal beverage, 100ml of fresh sweet whey were preheated to 50°C. Then the Moringaoleifera leaves powder (5,10 and 15g/100 ml) were mixed individually, and then blended in a mixer blender, the mixtures of beverages were kept for 20 hrs.The homogenized mixtures were filtrated through a muslin cloth and then mixed in a mixer blender again. The beverages obtained were filtered and filled into sterilized glass bottles (200 ml). The beverages were pasteurized in boiling water for 72°C to 15 Sec and the bottles stored in refrigerator for use.

Chemical Analysis

Moisture, protein, ash, lactose, crude fiber content, amino acids and vitamins assay was carried out on HPLC by following the respective methods as given in **AOAC (2012).**Potassium, magnesium, sodium, calcium, iron, phosphorus, zinc, manganese, and copper were determined using perkin Elmer 2380, atomic absorption spectrophotometerwere determined according the method of (**AOAC,2012**). All determinations were done in triplicate. The carbohydrate contents were tested quantitatively by the phenol–sulphuric acid method (**Chaplin and Kennedy, 1986**).

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Analysis of Phytochemicals

Phytochemical analysis including; tannin (**Polshettiwar*et al.*, 2007**), alkaloids and saponin (**Oloyed, 2005**), flavonoids (**El-Olemy*et al.*, 1994**) and total phenol (**Mc-Donald *et al.*, 2001**) were performed on the powder of *Moringaoleifera* leaves as well as prepared sweet whey beverage.

Antioxidant activity measurement

DPPH assay

The scavenging activity of the *Moringaoleifera*leaves powder on DPPH radicals was assayed according to the method described by (**Roche *et al.*, 2005**). Thirty microliters of aqueous solution containing various concentrations of the moringaleaves extract powder (50–150ug/ml) were mixed with 3ml of 0.2mM DPPH in HPLC methanol. Absorbance at 515 nm was determined after adding the extract. The DPPH radical scavenging activity of the test substance was calculated by the following equation:

Antioxidant activity (%) = $(A_{Control} - A_{sample})/A_{control}$ X 100

Where: $A_{control}$, was the absorbance of the control sample

and A_{sample}, the absorbance in the presence of the sample.

β-Carotene/Linoleic Acid assay

The β-carotene solution was prepared by dissolving 2 mg β-carotene in 10 mL chloroform; 1 mL of this β-carotene-chloroform solution was mixed with 20 mg linoleic acid and 0.2 g Tween 40. Subsequently, the chloroform was removed by a rotary evaporator at 45 °C. Distilled water (50 mL) was slowly added with vigorous agitation to form an emulsion. Emulsion aliquots (5 mL) were transferred with 0.2 mL of the extracts different concentrations (50-150µg/mL). Control samples were prepared with 0.2 mL methanol devoid of extract (**Shahidi*et al.*, 2001)**. As soon as the emulsion was added to each tube, absorbance was read at 470 nm against blank (zero time). Tubes were placed in a water bath at 50 °C, and oxidation was monitored by absorbance at 15 min intervals until the color of β-carotene in the control sample had disappeared (105 min).

BHA and TBHQ were used as references, andthe analyses were performed in triplicate. Antioxidant activity (AA) was calculated as percent inhibition relative to the control:

$\%AA = [1 - (Ai - At)/(A'i - A't)] \times 100$

Ai = absorbance of sample at zero time, *At*= absorbance of sample after incubation (105 min) at 50 °C, *A'i*= absorbance of control at zero time, and *A't*= absorbance of control after incubation (105 min) at 50 °C.

Sensory evaluation

Each sample was tested for colour, mouthfeel, flavor, sweetness, appearance and overall acceptability by 10 panelists. Each sensory characteristic was scored on an increasing scale from 1 (bad) to 9 (excellent). The evaluation was done by ten stuff members of Food Science Department and Faculty of Agriculture and Home Economy Department, Faculty of Specific Education, Ain Shams University **Suzan *et al*. (1994).**

Volatile compoundsextraction

The aroma volatiles in headspace of samples were isolated using a dynamic headspace system. The samples were purged for ~3 hrs. with nitrogen gas (grade of N_2> 99.99 %) at a flow rate100 ml/min. The headspace volatiles were swept into cold traps containing diethyl ether andpentane (1:1, v/v) and hold at –10^{o}C. Solvents containing the volatiles were dried oversodium sulfateanhydrous for 1h and evaporated under reduced pressure to obtain juice volatiles.

Gas Chromatography (GC) Analysis

The analysis performed using Perkin Elmer Auto system equipped with flame ionization detector (FID) and a fused silica capillary column DB-wax (60 m X 0.32 mm X 1 mm). The oven temperature was maintained

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initially at 55 °C for 5 min, then programmed from 55 to 170°C at a rate of 2°C/min. Helium was used at a flow rate 1.0 ml/min as carrier gas. The injector and detector temperatures were 220 and 250°C, respectively. The retention indices (Kovats index) of the separated volatile components were calculated with hydro-carbons (C_6-C_{22}) asreferences.

Gas Chromatography-mass Spectrometry (GC-MS) Analysis

Isolation, identification, and quantification of the volatile compounds were performed using a gas chromatograph (Hewllet-Packard (5890)/mass spectrometry and operated with the MS Workstation software. The GC-MS system was equipped with DB-wax column (Varian, Inc. Walnut Creek, CA; 60 m X0.25 mm X 1.0 mm film thickness). Column temperature began at 55°C and held for 5 min, increased 2°C per minute to 170°C, and finally increased 10°C per minute to 230°C and kept at this temperature for 10 min. The constant column flow was 1 ml/min, using helium as carrier gas.

Compounds Identification

The linear retention index (RI) values for unknowns were determined based on retention time data obtained by analyzing a series of normal alkanes (C_6-C_{22}). Volatile components were positively identified by matching their RI values and mass spectra with those of standards, also run under identical chromatographic conditions in the laboratory **(Adams, 2007)**.

Statistical Analysis

All experiments were carried out in triplicate and the results are expressed as mean±SD. Duncan's multiple range tests were used to compare the difference among mean values of beverage's properties at the level of 0.05 and SAS software (version 9.1; statistical analysis system institute Inc., Cary, NC, USA) was used for analysis **(SAS, 2006)**.

Results and Discussion

The proximate composition of whey beverage fortified with *Moringaoleifera*leaves powder (MOLP) are shown in **Table (1).**The results revealed thatmoisture, carbohydrate, protein, fat, lactose, fiber and ash were 7.85%, 31.78%,38.2%,4.17%,0.79%,7.45% and 6.80%,respectively in MOLP. The proximate values obtained in this study for the MOLP is comparable with the value obtained for leaves by**Moyo *et al.* (2013).** Fortification with MOLP showed an increase in protein, lactose, crude fiber, ash and fat with increase in the levels of MOLP and decrease in moisture content **Table (1)**. Moisture, carbohydrate, protein, fiber, fat and ash contents varied in the range 89.96-95.73%, 1.14-3.40%, 0.98-3.22%, 0.01-0.61%,0.33-0.38%,0.23-0.27% from T_1-T_3, respectively.

The fortification with MOLP at applied concentrations did not have any significant effect on pH of prepared whey beverage. The obtained results showed a significant ($P \leq 0.05$) increase in protein content that exhibited 328.6% in T_3 as compared to control**Table (1).** This increase may be due to the presence of high concentration in MOLP with low moisture content (**Madukwe *et al*., 2013).**

The results presented in **Table 2** summarize the mineral composition of MOLP as well as the fortified whey beverages with three concentration. Calcium had the highest value of 945 mg/100g followed by potassium 692 mg/100g and phosphorus had the least value of 145 mg/100g among the macro-elements (**Table 2**). The fortified sweet whey beverages showed a significant increase in a dose dependent manner in all macro and microelements as compared to control.

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Table 1. Major chemical constituent of *Moringaoleifera* leaves powder (MOLP) and sweet whey beverage (SWB) fortified with three concentrations

Treatment	pH	Moisture	Carbohydrate	Protein	Fat	Lactose	Fiber	Ash
MOLP	ND	7.85±0.14 ^{E}	31.44±0.42^{A}	38.1±0.96^{A}	4.17±0.01^{A}	0.79±0.19 ^{E}	7.40±0.042^{A}	6.80±0.13^{A}
SWB	5.26±0.12^{A}	95.73±0.12 ^{A}	ND	0.95±0.35^{D}	0.20±0.05^{E}	2.25±0.73^{C}	ND	0.18±0.91^{E}
T_1	5.38±0.43^{A}	92.73±0.43 ^{B}	1.14± 0.21 ^{D}	0.98±0.32^{E}	0.33±0.04 ^{D}	2.09±0.82^{D}	0.02±0.15^{C}	0.23±0.64^{D}
T_2	5.49±0.17^{A}	90.98±0.57^{C}	2.27±0.53^{C}	1.86±0.04 ^{C}	0.36±0.07 ^{C}	2.27±0.72^{B}	0.03±0.52 ^{C}	0.25±0.83^{C}
T_3	5.52±0.19^{A}	89.96±0.84^{D}	3.40±0.56^{B}	3.20±0.52 ^{B}	0.38±0.03 ^{B}	2.47±0.56^{A}	0.58±0.46 ^{B}	0.27±0.78^{B}

* Data are presented as means ± SD (*n=3*).

A,B,C.D: Means with different letter among treatments in the same column are significantly different($P \leq 0.05$)

T_1, T_2, T_3areMOLPconcentrations (5 , 10 and 15%) respectively in sweet whey beverage

ND= Not detected

Table 2. Minerals composition (mg/100g) of sweet whey beverage fortified with three concentrations *of Moringaoleifera* leaves powder

	Macro- elements				Micro-elements			
Treatment	**Calcium**	**Magnesium**	**Potassium**	**Phosphorus**	**Zinc**	**Manganese**	**Copper**	**Iron**
MOLP	945	379	692	145	28.9	94.3	7.64	358
SWB	66.40	11.6	85.1	44.6	235	0.05	0.01	0.21
T_1	648.7	313.3	483.3	143.7	11.17	57.27	5.73	260.2
T_2	658	349	492	143	21.7	84.30	6.42	271
T_3	667.3	384.7	500.8	142.3	32.23	111.33	7.11	281.8

T_1, T_2, T_3 are MOLPconcentrations (5, 10 and 15%) respectively in sweet whey beverage

Table 3.Vitamins analyses of MOLP, sweet whey beverage fortified using different levels of *Moringaoleifera* leaves powder

Treatment	Vit. (A) µg	Vit. C ppm	Nicotinic ppm	Thiamin ppm	Pyridoxin ppm	Folic acid ppm	Ribiflavin ppm	B_{12} ppm
MOLP	4352.16	101.43	332.83	12.47	17.80	8.55	11.54	143.88
SWB	ND	ND	3.05	0.11	0.15	0.14	0.72	2.75
T_1	11.46	64.61	40.63	25.01	13.06	16.01	12.02	81.49
T_2	11.97	83.02	60.41	14.87	17.44	63.38	12.09	128.56
T_3	12.48	97.71	24.55	18.69	20.76	117.59	21.36	119.54

T_1, T_2, T_3 areMOLPconcentrations (5, 10 and 15%) respectively in sweet whey beverages; ND= Not detected

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Table 4. Phytochemical analysis in sweet whey beverage fortified using different levels of *Moringaoleifera* leaves powder

Phytochemical Treatment	Flavonoids (Quercetinmg/ml)	Alkaloids (vincristine mg/ml)	Saponin	Phenol (gallic acid mg/ml)	Tannins (tannic acid mg/ml)	Glycosides
***MO*LP**	34.6±0.35 ^{A}	2.32±0.07^{A}	0.56±0.78^{A}	1.14±0.60^{A}	0.09±0.02 ^{A}	0.02±0.01^{AB}
T_1	15.8±0.45^{D}	1.37±0.05^{C}	0.26±0.38^{B}	0.99±0.45^{B}	0.03±0.57^{B}	0.02±0.05^{B}
T_2	23.9±0.20^{C}	2.12±0.13^{B}	0.50±0.58 ^{A}	1.09±0.28^{A}	0.06±0.12^{A}	0.03±0.03 ^{A}
T_3	31.3±0.56 ^{B}	2.22±0.55^{AB}	0.53±0.02^{A}	1.11±0.44^{A}	0.08±0.02 ^{A}	0.05±0.07^{AB}

* Data are presented as means ± SD (*n=3*).A,B,C.D:Means with different letter among treatments in the same column are significantly different($P \leq 0.05$)

T_1, T_2, T_3areMOLPconcentrations (5 , 10 and 15%) respectively in sweet whey beverage

Table 5. The free radical scavenging assay of *Moringaoleifera* leaves powder in sweet wheybeverage at different levels

Treatments	DPPH (%)			β-Carotene		
	50	100	150	50	100	150
T_1	59.3±1.16*	68.6±0.63	84.2±0.71	48.2±0.82	52.6±0.91	72.5±0.85^{a}
T_2	67.4±0.85^{a}	71.8±0.18^{a}	87.8±0.53	51.8±0.75	57.4±0.63	73.8±0.12^{a}
T_3	68.7±0.92^{a}	72.4±0.51^{a}	89.4±1.12	59.6±0.83	61.8±0.49	75.3±0.23
BHA 200 ppm	88.6±0.07			76.3±0.03		
TBHQ 200 ppm	92.6±0.03			79.4±0.02		

- Data are presented as means ± SD (n=3). Data in the same column with different superscript letters are statistically different ($P \leq 0.05$)

T_1, T_2, $T_3$are MOLP concentrations (5, 10 and 15%) respectively in sweet whey beverage

Table 6. Effect of MOLP fortification on sensory evaluation of sweet whey beverage

Characteristics	Treatments		
	T_1	**T_2**	**T_3**
Colour	9.40±1.07^{a}	8.40±1.43^{b}	6.5.80±2.20^{c}
Mouthfeel	6.5.60±1.65 ^{a}	5.5.50± 1.58^{b}	5.30±1.16^{b}
Flavour	6.5.60±0.97 ^{a}	6.40±1.43^{b}	5.10±0.99^{c}
Sweetness	6.5.50±1.84 ^{a}	5.5.80±1.39 ^{b}	5.10±2.13 ^{c}
Appearance	6.5.90±1.29 ^{a}	6.20±1.32 ^{b}	5.60±1.78 ^{c}
OVA	9.50±1.35 ^{a}	7.5.80±1.32 ^{b}	6.5.00±2.54 ^{c}

* Data are presented as means ± SD (*n*=10). OVA: Overall acceptability

Means in each column with different superscripts (a,b and c) were significantly different ($P< 0.05$) from each other.

T_1, T_2, T_3 are MOLP concentrations (5, 10 and 15%) respectively in sweet whey beverage

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Table 7. Volatile compounds in SWB and fortification treatment (T_1) at 5%

Volatile compounds	RI[a]	SWB	T_1	Identification method [c]
		Aldehydes		
Acetaldehyde	592[b]	2.61	1.85	MS, RI, STD
Pentanal	981	0.79	0.65	MS, RI
Hexanal	1079	0.06	7.18	MS, RI, STD
Octanal	1280	1.57	1.43	MS, RI
Nonanal	1392	1.18	5.42	MS, RI, STD
Decanal	1495	3.78	3.28	MS, RI
Dodecanal	1685	2.74	2.63	MS, RI
		Alcohols		
Ethanol	672	2.73	2.46	MS, RI, STD
2-Butanol	1154	14.59	13.9	MS, RI, STD
Pentanol	1253	1.64	5.34	MS, RI
Hexanol	1358	0.78	7.21	MS, RI
Octanol	1552	0.21	1.37	MS, RI
		Acids		
Acetic acid	1439	8.14	5.92	MS, RI, STD
Prpionic acid	1521	5.91	4.63	MS, RI
2-methyl-propionic acid	1550	6.43	4.92	MS, RI
Butanoic acid	1607	6.72	4.31	MS, RI
3-methyl-butanoic acid	1651	4.95	3.95	MS, RI
Pentanoic acid	1715	0.48	0.39	MS, RI, STD
Hexanoic acid	1829	0.09	0.12	MS, RI
Heptanoic acid	1931	0.23	0.18	MS, RI
Octanoic acid	2043	0.17	0.25	MS, RI
Nonanoic acid	2144	0.54	0.38	MS, RI
Decanoic acid	2250	0.82	0.72	MS, RI
		Esters		
Butyl acetate	1075	11.75	10.42	MS, RI, STD
Ethyl nonanoate	1531	0.64	0.58	MS, RI
Methyl decanoate	1588	0.93	0.74	MS, RI

[a] Retention indices calculated from GC/MS data on the capillaries DB-wax column. [b]: values are expressed as relative area percentage

[c] Identification method: MS, identification by comparison with mass spectra stored in NIST library; RI, identification by comparison with published GC retention index, STD, identification supported by co-injection of standard compounds

The addition of MOLP at T_3 increased the calcium content from 66.40 to 667.3 mg/100g which was 1004.96% higher than the control. As recommendations of FAO, WHO 400 mg and 1200 mg calcium is required on daily basis for children of 1-3 years age and nursing women, respectively. Half of the total calcium requirement for nursing women may be easily and economically fulfilled by consuming one glass of 100 mL of T_3 sweet whey beverage fortified withMOLP. The highest value among the micro-minerals was iron with 358 mg/100 g followed by manganese with 94.3 mg/100 g (**Table 2**). MOLP contains a significant amounts of both macro and micro elements, which explain the increase in fortified sweet whey beverages. The therapeutic

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effects of MOLPhave been attributed to the combined actions of various bioactive components found in the plant that include trace metal ions**Gowrishankar *et al.*(2010)**.

All the concentrations used for fortification sweet whey beverage with MOLP showed an increase in vitamins concentrations especially folic acid which increase from 0.14 ppm in control sample to 117 ppm at T_3**(Table 3)** followed by B_{12} which exhibited 2.75 ppm and 119.54 ppm in control and T_3, respectively.

Phytochemicals are component of plant splay an important role in the treatment of diseases. The type and amount of various phytochemical in MOLP and fortified sweet whey beverage at three levels are presented in **Table (4)**. The obtained data showed that MOLP is a rich source of flavonoids 34.6 mg/ml and alkaloids 2.32 as well as total phenolic 1.14 mg/ml. While, addition of MOLP showed a significant ($P \leq 0.05$) increase in all phytochemicals in comparison between control and fortified treatments, no significant had occurred between T_2 and T_3 **(Table 4).**

Flavonoids have long been recognized to possess several biological activities such as antioxidant, anti-proliferative and anti-carcinogenic activities (**Akaneme, 2008).** The combination of alkaloids with saponins is reason of healing hypertension by MOLP **(Fahey, 2005).**The variation between our data and those obtained by **Sreelatha and Padma (2009)** may be due to various factors, including climatic and conditions and geographical location.

Antioxidant activity

DPPH radical scavenging ability is widely used as an index to evaluate the antioxidant potential of medicinal plants. The extent of DPPH radical scavenging at different concentrations (50-150 ug/ml) of MOLPwas measured and compared with BHA and TBHQ as the standards and the obtained results are given in **(Table 5).** The radical scavenging effect was found to increase with increasing concentrations of MOLP in sweet whey beverage.

The high antioxidant activity of whey beverage supplemented with MOLP shown in **Table 5,** could be attributed to vitamins and antioxidant compounds available in moringa such as the large amount of Vitaminssuch as A which recorded at 4352.16 ug/ g, as well as flavonoids that had the ability to scavenge hydroxyl radicals, superoxide anions and lipid peroxy radicals. (**Alan and Miller, 1996, Moyo*et al.*, 2011**). The major phytochemical responsible for antioxidant activity of plant materials is phenolic compounds. However, *Moringaoleifera*is a rich source of vitamin c and flavonoids which also exhibited the antioxidant activity (**Anwar *et al.* 2005).**

Sensory evaluation

The results of sensory evaluation include the colour, mouthfeel, flavor, sweetness, appearance and overall acceptabilityevaluation are shown in **Table 6**. As can be observedcolour and OVA of T_1 have gotten the highest degree as compared to others (scores of 9.40±1.07and 9.50, respectively).

Sensory evaluation showed that blend T_1 (5% MOLP) compared favorably with the other blends. The increase in MOLP significantly decreased the sensory properties of the beverage ($P< 0.05$) and the mean value of 9.40 for color in the T_1 prepared beverage decreased to 6.5.80 at T_3 (**Table 6**).

Volatile compounds

The volatile compounds of fresh sweet whey beverage (SWB) as well as fortification of SWB with MOLP at 5% (T_1) were analyzed by GC and GC-MS and the identified compounds with linear RI are given in **Table (7)**.

A total of 26 volatiles were identified in SWB and selected fortification sample at 5%, including 7 aldehydes, 5 alcohols, 11 acids and 3 esters. The most abundant identified volatile compounds were acids which represent 34.48% and 25.77% in SWB and T_1, respectively. Acetic acid was the most predominant acid in both investigated samples with 8.14% and 5.92% in SWB and T_1,respectively.

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Seven aldehydes in both investigated sample were identified by GC and GC-MS as well as RI after extraction using headspace technique. All the identified aldehydes are saturated including the major aldehyde is hexanal (7.18%) followed by nonanal (5.42%), decanal (3.28%), dodecanal (2.63%) and octanal (1.43%) in fortified sample with 5% MOLP which are likely to originate from lipid oxidation (**Kondyli*et al.*, 2003**) and have beenassociated with fatty and unclean flavors in dairy products (**Tomaino*et al.*, 2001**). The high concentration of acids and aldehydes compared to other volatile classes in the present study may be explain the rejection high fortified samples T_2 and T_3. Therefore, more detailed studies about the quantitative volatile and non-volatile compounds are in need.Aldehydes are known to present in liquid and dry whey products with significant important in flavor formation due to their low odour threshold and small molecular weight **(Karagul-Yuceer *et al.*, 2003, Carunchia *et al.*, 2005)**. Significant increase had occurred in hexanal after fortification which represent 0.06% and 7.18% in SWB and T_1, respectively compared to decrease in acetaldehyde which decrease from 2.61% in SWB to 1.85% in T_1.Acetaldehyde which had nutty and pungent flavor is considered the principal flavour in fermented another dairy products such as yogurt **(Ertekin and Guzel-Seydim, 2010)**. To the best our knowledge, little studies about moringa essential oil or whey beverage volatile are known, this the first trial to investigate the volatile composition of whey beverage fortified with MOLP.

Among the esters, butyl acetate, ethyl nonanoate and methyl decanoatewere identified with concentrations of 11.75%, 0.64%, 0.93%,respectively, in SWB. On the other hand, the same sequence of esters in T_1 were 10.42%, 0.58% and 0.74%, respectively. Esters characterized by fruity attributesare formed by the esterification of free fatty acids and alcohols (**McSweeney and Sousa, 2000**).

Conclusion

Sweet whey beverage fortified with MOLP at three levels showed an improvement in nutritional value of the beverage.While an increase in protein, fat, lactose, all phytochemical, vitamins and macro as well as microelements, the sensory evaluation decrease with MOLP increase. Therefore, the study will extend to investigate the nonvolatile and storage conditions on the prepared beverage.

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