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FULL PAPER

Organoleptic acceptability and nutritional evaluation of innovative *Moringa oleifera* leaves-based herbal teas incorporated various aromatic herbs

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Abstract

The current research aimed at selecting the highest acceptable mixtures of moringa-based herbal teas (MHTs) flavored with various aromatic herbs (AHs). Total phenolic content (TPC), total carotenoids (TC), total flavonoids (TF), total flavonols (TFL), antioxidant activity (AOA), and ascorbic acid (AA) contents of panel favored MHTs were investigated. HPLC analysis following acidic hydrolysis of MHTs to quantify some bioaccessible aglycones was investigated. Mixing *Moringa oleifera* leaves (MOL) with AHs significantly improved the organoleptic properties depending on the aroma strength of AHs. MHTs with 15-25% ginger rhizomes (GR) and peppermint (PM), MHTs with 25-35% domestic mint (DM), cinnamon bark (CB), and mountain mint leaves, and MHTs with 35-45% anise seeds (AS), fennel seeds (FS) and green tea (GT) were approved 16 MHTs, organoleptically. Accepted MHTs flavored with GR and AS demonstrated high TPC and TC, while MHTs with MM exhibited high TF and TFL, whereas the highest AOA was recorded for MHTs with GT, CB, and AS. A remarkable increase in quercetin and kaempferol contents in MHTs with GR and catechin and luteolin contents in MHTs with GT was recorded. It could be concluded that prepared MHTs offer significant information for consumers to turn their food preferences into healthy choices regards regular drinks.

1. Introduction

Plants are known, among others, to be major sources of bioactive compounds with immune system enhancing, anticancer, antioxidant, antimicrobial, and anti-inflammatory effects (Mehany *et al.*, 2021). Natural products with potential health benefits are rapidly being consumed, and new bioactive compounds are being constantly discovered (Fridlender *et al.*, 2015; Yang *et al.*, 2016; Mehany *et al.*, 2021). As approached globally, promoting health by focusing particularly on natural capabilities is required. Recently, cultivation and awareness of moringa were remarked to be increased in Saudi Arabia (Alaklabi, 2015; Mridha, 2015). However, the high content of polyphenols such as tannins gives moringa its astringent taste, reducing the consumer's acceptability (Manguro and Lemmen, 2007). Interestingly, current research may involve an innovative approach to combining MOL with AHs to enhance its organoleptic acceptability (Sugahara *et al.*, 2018).

Moringa oleifera Lam belongs to the Moringaceae family and is a rapidly growing perennial foliaged tree broadly planted due to its great adaptability to climatic circumstances (Teixeira *et al.*, 2014). It is used as food, in medicines, and for industrial purposes of its nutritional, therapeutic, and prophylactic characteristics were concerned (Olayaki *et al.*, 2015; Balakrishnan *et al.*, 2019; Al Zhrani *et al.*, 2021; González-Burgos *et al.*, 2021). Recently, various parts of *M. oleifera* demonstrated hypolipidemic, hypoglycemic, and hepatoprotective effects (Balakrishnan *et al.*, 2019; Al Zhrani *et al.*, 2021). MOL contains substantial amounts of vitamins, considerable quantities of proteins, minerals, and phytonutrients (Amaglo *et al.*, 2010) with high antioxidant capacities (Paula *et al.*, 2017; Sugahara *et al.*, 2018). Many phytochemicals such as kaempferol and quercetin glycosides as main flavonoids were identified (Saini, Shetty, Prakash *et al.*, 2014; Leone *et al.*, 2015). However, additional phenolics were characterized as gallic acid, syringic acid, quercetin 3-*O*-beta-glucoside, and rutin (Manguro and Lemmen, 2007). Many parts of the *M. oleifera* tree have been recognized as a good

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source of phenolic acids, flavonoids, glucosinolates, carotenoids, and highly bioavailable minerals (Saini, Shetty, Prakash *et al.*, 2014; El Sohaimy *et al.*, 2015). AHs such as mint and peppermint are effective and widely used in tea, flavoring foods, and beverages, and their essential oils are also used in chewing gum, candy, toothpaste, mouthwash, aromatherapy, pharmaceuticals, and antimicrobials (Cappellari *et al.*, 2019; Uribe *et al.*, 2016). The mint leaves are rich in phenolic compounds that make up 20% of the dry weight. In an infusion with a fresh taste and particular scent, 75% of these compounds can be extracted (Figueroa Perez *et al.*, 2014). Cinnamon bark powder has been scientifically verified and has several biological activities and health benefits as a rich source of natural antioxidants (Abeysekera *et al.*, 2019). Ginger has been commonly used as a seasoning or traditional condiment for various foods and beverages. Phytochemical studies show that ginger has antioxidant and anti-inflammatory activity, and some of them have the potential for cancer prevention (An *et al.*, 2016). Anise seeds showed strong antioxidant activity, reducing power, DPPH radical and superoxide anion scavenging, hydrogen peroxide scavenging, and metal chelating compared to various standards such as BHA, BHT, and α-tocopherol. Moreover, extracts of aniseed seeds had noticeable antimicrobial activity against gram-positive and gram-negative bacteria (Gülçın *et al.*, 2003; Mohammad Al-Ismail and Aburjai, 2004). Green tea contains many important compounds such as phenolics, flavonoids, minerals, vitamins, pigments, and volatile compounds (Roshanak *et al.*, 2016). Interestingly, numerous epidemiological studies have linked tea flavonoids to health benefits such as cancer prevention, cardiovascular diseases, microbial diseases, diabetes, obesity, and oxidative stress prevention (Roshanak *et al.*, 2016). Fennel seeds showed higher phenolics, flavonoid content, and antioxidant capacity and revealed higher antibacterial activity offering excellent prospects for preventive treatment of various disease complications (Salami *et al.*, 2016).

The development of new moringa-based herbal tea products will provide new applications for underused plants such as MOL and provide consumers with new alternatives to traditional teas. The research would also demonstrate the potential of MOL to produce different MHTs with high organoleptic acceptance. The work would, in particular, expand the awareness of herbal teas' nutritional and organoleptic features as healthy alternatives to traditional tea and coffee. Therefore, the main goal of the research is to determine the organoleptic and nutritional properties of naturally flavored *M. oleifera* leaves-based herbal tea with peppermint, domestic and mountain mint leaves, green tea, ginger rhizomes, cinnamon bark powders, anise, and fennel seeds to produce MHTs with consumer satisfactory. Phytochemicals and antioxidant activity of favored selected MHTs were investigated. They were considering the acidic environment typically found in the gut tract, the expected bioaccessible flavonoids such as quercetin, kaempferol, catechin, and luteolin after acidic hydrolysis were quantified.

2. Material and methods

2.1 Collection of MOL and AHs

Dried MOL was collected from Al Owed field, Organic Nadawy, Gazan, Saudi Arabia, from the 2018-season. The leaves were checked for removing the rods, stems, and yellow leaves. Different flavors ingredients such as mountain mint (MM), *Mentha arvensis* L., Domestic mint (DM), *Mentha varidis* L., peppermint mint (PM), *Mentha piperita* L., green tea GT), *Camellia sinensis* L., ginger rhizomes powder (GR) *Zingiber officinale* L., cinnamon bark powder (CB) *Cinnamomum burmannii* L., anise seeds (AS) *Pimpinella anisum* L., and fennel seeds (FS) *Foeniculum vulgare* Mill. were obtained from spices in local markets at Buraidah city, Qassim region, SA. After both MOL and AHs were cleaned, dried materials were kept cool at 4±1°C and dried until further use.

2.2 Preparation of different MHTs

Dried MOL was milled (Christison Laboratory mill, U.S.A). Consequently, MOL powder was mixed individually with each AH according to exhibited ratios in Table 1 then each mixture was filled in a clean and dry 500 mL cape screw bottle (5 g/each bottle). For hot tea preparation, 500 mL of boiling distilled water was added to each bottle, closed, mixed, and left for 5 mins, then filtered using three layers of cheesecloth. The hot clear extracts were then filled in a thermos to keep them hot for the organoleptic evaluation.

2.3 Analytical methods

2.3.1 Determination of ascorbic acid

The ascorbic acid content using the 2,6-dichloro phenol indophenol titrimetric method was determined, and content was expressed as mg 100 g^{-1} fw according to Silva *et al.* (1999).

2.3.2 Phytochemicals analysis of naturally flavored Moringa herbal tea

Total phenolic content (TPC) was determined using the Folin-Ciocalteau method, and TPC was expressed as milligram gallic acid equivalents per gram sample (mg GAE 100 g^{-1} dw) according to Bettaieb *et al.* (2010). Total carotenoids (TC) content was determined colorimetrically as described in the modified method of Barakat and Rohn (2014). The antioxidant activity as DPPH radical scavenging activity (DPPH-RSA) was determined colorimetrically using 2,2-diphenylpicrylhydrazyl (DPPH) radical. The DPPH free radical inhibition percentage was calculated; results were interpreted toward plotting the Trolox standard and were presented as µmol TE g^{-1} dw (Zhang and Hamauzu, 2004). Total flavonoid (TF) and total flavonols (TFL) contents were determined, and results were presented as mg quercetin equivalent (QE) g^{-1} using the method of Mohdaly *et al.* (2013) and Kumaran and Karunakaran (2007), respectively.

2.3.3 Quantification of flavonoids in different MHTs by HPLC after acidic hydrolysis.

Precisely, two grams of each naturally flavored moringa herbal tea mixture was brewed in 50 mL boiled water and then kept for 5 min at 95±1°C. After centrifugation for 10 mins at 3220×*g*, an aliquot of 40 mL of the extract was taken from the supernatant. Freeze -drying different herbal tea extracts and dissolving the obtained residue in 2 mL of HPLC d.H_2O followed. Consequently, to identify the corresponding aglycone structures, acidic hydrolysis of different herbal tea extracts in a solution consisting of 1.6 M HCl was carried out according to Barakat and Rohn (2014). After refluxing at 90°C for 2 hrs, the extract was cooled down, sonicated for 5 mins then the volume was adjusted. The extract was then filtered through a 0.45 µm filter, subjected to HPLC, and the peaks obtained were identified by comparing with different aglycone standards. According to Kim et al. (2006), HPLC analysis will be assayed with slight modifications using an Agilent Technologies 1100 series liquid chromatograph equipped with an auto-sampler and a diode-array detector. The analytical column is Agilent Eclipse XDB C18 (250×4.6 µm; 5 µm) with a C18 guard column (Phenomenex, Torrance, CA) applying a gradient system of 95% eluent (A) 0.1% formic acid in the water, and 5% eluent (B) 0.1% formic acid in acetonitrile at a flow rate of 0.7 mL min^{-1}. Chromatograms were recorded at 320 and 360 nm, and identified peaks for quercetin, kaempferol, catechin, and luteolin were interpreted, then contents were expressed as mg 100 g^{-1} MHT on dry-based weight.

2.4 Organoleptic evaluation

Immediately after preparation, an organoleptic evaluation of hot MHTs by twenty well-trained panelists aged 25 – 60 years comprised of post-graduate students and staff members was done. They preliminary received an intensive description of the used procedure and evaluated properties. Panelists were asked to evaluate MHTs extracts toward color, aroma, taste, Aftertaste, astringency, and overall acceptability. A 7-point hedonic scale (7 being 'like extremely', 4 'like accepted', and 1 being 'dislike extremely') has been used. Results were subjected to analysis of variance and average of the mean values of the attributes mentioned above. Their standard error was calculated according to a modified protocol based on De-Heer (2011).

2.5 Data analysis

The statistical analysis was carried out using the SPSS program (ver. 19) by applying the analysis of variance (ANOVA) regarding experimental design. The application of significance level at 0.05 and Tukey's test was achieved according to Steel *et al.* (1997).

3. Results and discussion

3.1 Organoleptic characteristics of different MHTs

The organoleptic appeal of tea, like all food products, is an important consideration in the development of new products. Interestingly, herbal tea is gaining growing market interest due to a growing awareness of health benefits derived from its uses (Oduro *et al.*, 2011). Seventy-two mixtures were prepared by mixing MOL with eight aromatic plants used as AHs, such as edible parts of MM, DM, GT, PM, GR, CB, AS, and FS. The mixing ratios started with 90% MOL and ended with 50%, and the 100% portion was completed by AHs (Table 1). Hot MHTs extracts prepared from seventy-two mixtures were organoleptically evaluated (data not shown). All organoleptic properties for pure MOL hot tea presented sores less than 4 indicating lower panels acceptance. This may be due to the astringent taste of pure moringa teas (Manguro and Lemmen, 2007; Oduro *et al.*, 2011; Famurewa *et al.*, 2017). However, a highly significant acceptable score in color, aroma, flavor, Aftertaste, astringency, and overall acceptability was recorded. The favored selected MHTs were organoleptically reevaluated, and the results were illustrated in Table 2. Only sixteen mixtures were selected after the panelists were asked to select the best-favored mixtures, which present both flavor of moringa and the added AHs. Indeed, the difference in the mixing ratio among the selected favored mixtures makes it very difficult to be comparable. Hence obtained scores were higher than 4 'like accepted' in all selected mixtures, it could be recommended for scaling up in commercial production as ready to use herbal teas, or filter bagged MHTs. The highest score mixtures were MG (80:20), MF (55:45), MGT (55:45), MGT (55:45), MMM (65:35), and MDM (73:30) in color, aroma, taste, Aftertaste, astringency, and overall acceptability, respectively. Obviously, the

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Table 1. Mixtures of *M. oleifera* dried leaves with different natural flavorings for producing herb tea mixtures

Moringa herbal tea mixture		Natural flavoring ingredients							
		MM	DM	GT	PM	GR	CB	AS	FS
M. oleifera dried leaves	M1	90:10	90:10	90:10	90:10	90:10	90:10	90:10	90:10
	M2	85:15	85:15	85:15	85:15	**85:15**	85:15	85:15	85:15
	M3	80:20	80:20	80:20	**80:20**	**80:20**	80:20	80:20	80:20
	M4	75:25	**75:25**	75:25	**75:25**	75:25	**75:25**	75:25	75:25
	M5	**70:30***	**70:30**	70:30	70:30	70:30	**70:30**	70:30	70:30
	M6	**65:35**	65:35	65:35	65:35	65:35	65:35	**65:35**	65:35
	M7	60:40	60:40	**60:40**	60:40	60:40	60:40	**60:40**	**60:40**
	M8	55:45	55:45	**55:45**	55:45	55:45	55:45	55:45	**55:45**
	M9	50:50	50:50	50:50	50:50	50:50	50:50	50:50	50:50

Bold values indicated the selected mixtures after organoleptically preference. MM: mountain mint leaves, DM: domestic mint leaves, GT: green tea leaves, PM: peppermint leaves, GR: dried ginger rhizomes, CB: cinnamon bark powder, A: Anise seeds, F: fennel seeds.

mixing ratios clearly depend on the strength of flavoring plants for changing the organoleptic characteristics of the final drinks (Oduro *et al.*, 2011; Famurewa *et al.*, 2017). Mixing GR and PM in rates not exceeding 25% with MOL confirms their strength to increase the panelist's susceptibility to moringa herbal tea due to their dense aroma compounds (Ali *et al.*, 2018; An *et al.*, 2016; Fatiha *et al.*, 2015). MM, DM and CB have increased the acceptance levels of different MHTs when mixed in ratios not more than 35% confirming their moderate aroma. This can be attributed to the increase in MM, DM, and CB to MOL, as similarly shown with hibiscus-moringa teas (Oduro *et al.*, 2011; Famurewa *et al.*, 2017). Mixing of GT, FS, or AS with MOL in rates not exceeding 45% exhibited highly accepted moringa-based herbal teas, Table 2. It is worth mentioning that increasing the AHs ratio increased the organoleptic susceptibility of prepared moringa drinks, which may be due to the astringent taste of moringa as confirmed (Oduro *et al.*, 2011; Famurewa *et al.*, 2017). Hence, the aroma strength of AHs and panelists' preferences were mainly affected by the mixing ratio, the content of the bioactive compound, and bioaccessible flavonoids were highlighted (Figure 1, Tables 3 and 4).

3.2 Ascorbic acid content

Ascorbic acid has received much attention and rightly so as a super antioxidant and immune system

Table 2. Organoleptic evaluation of hot teas prepared from favored naturally flavored *M. oleifera* herbal teas.

Moringa herbal tea mixture		Organoleptic properties					
		Color	Aroma	Taste	Aftertaste	Astringency	Overall acceptability
MMM	70:30	4.83±0.14^{abcde}	5.00±0.25^{ab}	5.00±0.25^{ab}	5.17±0.14^{abcd}	5.33±0.29^{bcd}	5.60±0.09^{bcd}
	65:35	4.50±0.25^{abc}	6.17±0.14^{de}	5.83±0.38^{bc}	5.83±0.38^{cd}	6.47±0.13e^{f}	6.07±0.26^{d}
MDM	75:25	4.97±0.48^{abcdef}	5.00±0.20^{bc}	5.33±0.52^{abc}	4.93±0.23^{abcd}	5.50±0.05^{bcde}	5.43±0.43^{bcd}
	70:30	5.70±0.31^{defg}	5.50±0.44^{bcd}	6.10±0.13^{bc}	5.93±0.38^{cd}	6.30±0.13^{f}	6.47±0.13^{d}
MGT	60:40	4.57±0.28^{abcd}	5.00±0.10^{ab}	5.10±0.39^{ab}	5.1±0.26^{abcd}	4.83±0.18^{abc}	4.87±0.18^{abc}
	55:45	5.30±0.53^{bcdef}	5.97±0.34^{cde}	6.48±0.25^{c}	6.00±0.39^{d}	6.23±0.15^{def}	5.87±0.28^{cd}
MPM	80:20	4.47±0.03^{ab}	5.00±0.10^{a}	5.20±0.30^{ab}	4.37±0.12^{ab}	4.73±0.10^{abc}	5.50±0.44^{bcd}
	75:25	5.63±0.08^{cdefg}	5.63±0.03^{bcd}	5.93±0.26^{bc}	5.30±0.09^{bcd}	5.90±0.26^{def}	6.13±0.32^{d}
MG	85:15	5.17±0.29 ^{abcdef}	5.00±0.32^{ab}	5.00±0.22^{ab}	4.83±0.29^{abc}	4.8±0.23^{abc}	4.90±0.38^{abc}
	80:20	6.47±0.13^{h}	6.10±0.3^{de}	6.13±0.32^{bc}	5.97±0.25^{d}	4.73±0.20^{abc}	6.20±0.15d
MC	75:25	5.20±0.30 ^{abcdef}	5.00±0.37^{ab}	5.10±0.09^{ab}	4.17±0.15^{a}	4.63±0.08^{ab}	4.37±0.12^{a}
	70:30	5.73±0.45^{efg}	6.13±0.2^{de}	5.53±0.60^{bc}	5.83±0.29^{cd}	6.23±0.19^{def}	5.53±0.15^{bcd}
MA	65:35	4.10±0.26^{a}	5.00±0.22^{a}	5.83±0.29^{bc}	4.17±0.35^{a}	4.20±0.26^{a}	4.67±0.36^{ab}
	60:40	6.03±0.20^{fg}	5.53±0.5^{bcd}	6.17±0.25^{bc}	5.33±0.37^{bcd}	5.40±0.41b^{cde}	5.47±0.06^{bcd}
MF	60:40	4.27±0.10^{ab}	5.00±0.05^{a}	4.23±0.18^{a}	4.47±0.41^{ab}	4.27±0.16^{a}	4.37±0.46^{a}
	55:45	6.00±0.39^{fg}	6.37±0.33^{de}	5.50±0.18^{bc}	5.97±0.24^{d}	5.63±0.51^{cdef}	5.90±0.26^{cd}

Values are presented as mean±SD. Values with the different superscript within the same column are significantly different (P<0.05). MMM: flavored moringa with mountain mint leaves, MDM: flavored moringa with domestic mint leaves, MGT: flavored moringa with green tea leaves, MPM: flavored moringa with peppermint leaves, MG: flavored moringa with dried ginger rhizomes, MC: flavored moringa with cinnamon bark powder, MA: flavored moringa with anise seeds, MF: flavored moringa with fennel seeds.

Table 3. Phytochemicals and antioxidant activity of favored naturally flavored *M. oleifera* leaves herb tea mixtures.

Moringa herbal tea mixture		Total phenolic compounds [mg GAE g^{-1} dw]	Carotenoids [mg g^{-1} dw]	Flavonoids [mg QE g^{-1} dw]	Flavonols [mg QE g^{-1} dw]	Antioxidant activity [μmol TE g^{-1} dw]
MMM	70:30	78.88±2.28^{a}	19.54±0.56^{de}	44.62±1.29^{g}	24.09±0.70^{gh}	71.02±2.05^{ef}
	65:35	76.28±2.20^{a}	19.36±0.56^{de}	47.51±1.37^{g}	25.41±0.73^{hi}	75.59±2.18^{f}
MDM	75:25	77.13±2.23^{a}	17.99±0.52^{cd}	33.05±0.96^{bc}	18.44±0.53^{b}	54.59±1.58^{a}
	70:30	73.67±2.13^{a}	17.46±0.50^{bc}	34.20±0.99^{bcd}	18.88±0.55^{bc}	56.79±1.64^{bc}
MGT	60:40	122.89±3.55^{b}	19.96±0.58^{ef}	34.49±0.99^{bcd}	20.75±0.6^{cde}	94.51±1.29^{g}
	55:45	126.44±3.65^{b}	19.87±0.57^{ef}	35.38±1.12^{cde}	21.32±0.62^{ef}	104.63±1.29^{hi}
MPM	80:20	82.62±2.39^{a}	19.32±0.56^{de}	35.95±1.04^{cdef}	20.01±0.58^{bcde}	67.53±1.95^{de}
	75:25	79.66±2.30^{a}	19.00±0.55^{cde}	38.11±1.10^{ef}	20.96±0.61^{def}	73.51±2.12^{ef}
MG	85:15	138.54±4.00^{c}	21.33±0.62^{f}	31.75±0.92^{b}	21.14±0.61^{ef}	63.38±1.83^{cd}
	80:20	153.23±4.43^{e}	21.56±0.62^{f}	33.22±0.96^{bc}	22.78±0.66^{fg}	69.98±2.02^{ef}
MC	75:25	142.12±4.11^{cd}	18.28±0.53^{cde}	36.76±1.06^{def}	24.91±0.72^{hi}	93.84±2.71^{g}
	70:30	151.65±4.38^{de}	17.81±0.51^{cd}	38.65±1.12^{f}	26.65±0.77^{i}	103.89±3.01^{hi}
MA	65:35	151.05±4.37^{de}	19.21±0.56^{cde}	33.60±0.97^{bcd}	18.74±0.54^{b}	98.77±2.85^{gh}
	60:40	159.14±4.60^{e}	19.01±0.55^{cde}	34.50±1.09^{bcd}	19.10±0.55^{bcd}	106.66±3.0^{8i}
MF	60:40	121.79±3.52^{b}	16.07±0.46^{ab}	20.21±0.58^{a}	12.32±0.36^{a}	57.52±1.66^{bc}
	55:45	125.21±3.62^{b}	15.50±0.45^{a}	21.01±0.61^{a}	11.84±0.34^{a}	59.26±1.71^{bc}

Values are presented as mean±SD. Values with the different superscript within the same column are significantly different ($P<0.05$). MMM: flavored moringa with mountain mint leaves, MDM: flavored moringa with domestic mint leaves, MGT: flavored moringa with green tea leaves, MPM: flavored moringa with peppermint leaves, MG: flavored moringa with dried ginger rhizomes, MC: flavored moringa with cinnamon bark powder, MA: flavored moringa with anise seeds, MF: flavored moringa with fennel seeds.

Table 4. Effect of hot extraction on the content of quercetin, kaempferol, catechin, and luteolin in selected favored naturally flavored *M. oleifera* leaves herb tea mixtures following acidic hydrolysis.

Moringa herbal tea mixture		Flavonoid compounds [mg 100 g^{-1} dw]			
		Quercetin	Kaempferol	Catechin	Luteolin
MMM	70:30	5.42	2.83	8.76	6.18
	65:35	5.15	2.71	8.59	5.92
MDM	75:25	4.86	2.52	7.57	5.49
	70:30	4.62	2.41	7.40	5.26
MGT	60:40	5.56	3.10	23.87	15.81
	55:45	4.82	2.77	24.85	16.21
MPM	80:20	7.13	3.66	10.77	7.98
	75:25	5.10	2.66	8.18	5.80
MG	85:15	8.02	3.71	8.43	7.38
	80:20	6.72	3.06	6.63	5.96
MC	75:25	4.71	2.06	5.52	4.56
	70:30	4.50	1.89	5.03	4.21
MA	65:35	4.33	1.91	4.93	4.13
	60:40	4.11	1.76	4.48	3.80
MF	60:40	6.24	1.86	4.76	3.72
	55:45	6.64	1.79	4.48	3.49

Values are presented as means of duplicate. MMM: flavored moringa with mountain mint leaves, MDM: flavored moringa with domestic mint leaves, MGT: flavored moringa with green tea leaves, MPM: flavored moringa with peppermint leaves, MG: flavored moringa with dried ginger rhizomes, MC: flavored moringa with cinnamon bark powder, MA: flavored moringa with anise seeds, MF: flavored moringa with fennel seeds.

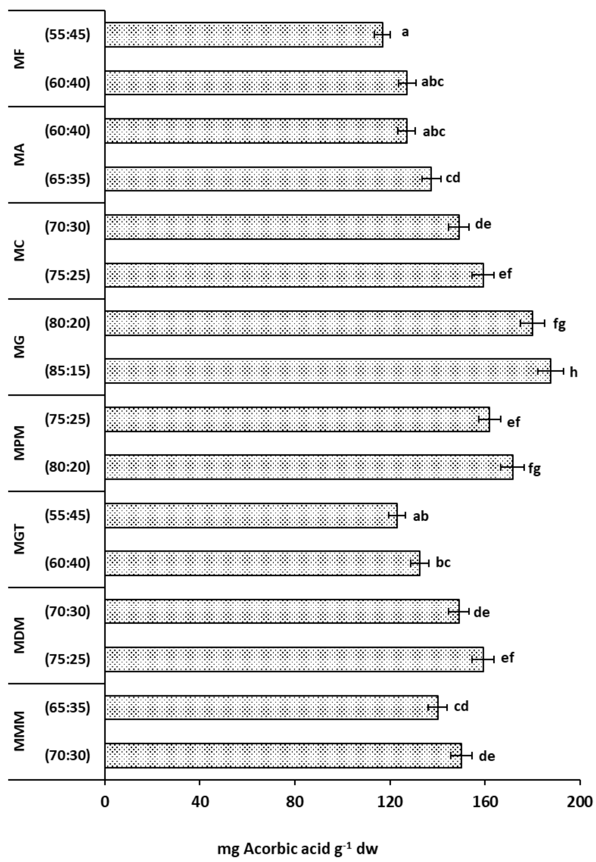

Figure 1. The ascorbic acid content in naturally flavored *M. oleifera* leaves herbal tea mixtures. Different alphabet notations above bars are significantly different ($P<0.05$). MMM: flavored moringa with mountain mint leaves, MDM: flavored moringa with domestic mint leaves, MGT: flavored moringa with green tea leaves, MPM: flavored moringa with peppermint leaves, MG: flavored moringa with dried ginger rhizomes, MC: flavored moringa with cinnamon bark powder, MA: flavored moringa with anise seeds, MF: flavored moringa with fennel seeds.

enhancer. However, higher levels of ascorbic acid in the blood can be the perfect dietary marker for overall health (Carr and Maggini, 2017). The function of ascorbic acid may include protection from defects in the immune system, cardiovascular disease, maternal health problems, eye disease, and even skin wrinkles (Zhang and Hamauzu, 2004). Figure 1 presents the ascorbic acid content in prepared mixtures of favored naturally flavored *M. oleifera* herbal teas. The ascorbic acid content ranged from 116.85 to 187.51 mg ascorbic acid g $^{-1}$ dw in MF (55:45) and MG (85:15). The highest ascorbic acid content was recorded in MG (85:15), while the lowest was recorded in MF (55:45) herbal teas. Obviously, MOL is a rich source of ascorbic acid and bioactive compounds even after dehydration (Oduro *et al.*, 2011; Leone *et al.*, 2015; Saini, Shetty, Prakash *et al.*, 2014). Indeed, increasing MOL in the mixtures increased ascorbic acid content, and decreasing the MOL affects the ascorbic acid content only with AHs low in ascorbic acid content (Saini, Shetty, Prakash *et al.*, 2014). Indeed, the variation in the mixing ratio among the selected favored mixtures makes it very difficult to be comparable.

3.3 Phytochemicals and antioxidant activity of different MHTs

Data in Table 3 demonstrate the TPC of different MHTs. In addition, phytochemicals such as TC, TF, and TFL and the antioxidant activity of different MHTs have been examined. TPC content ranged from 76.28 to 159.14 mg GAE g^{-1} dw in MMM (65:35) and MA (60:40), respectively. Preparing MHT with 85% MOL and 15% GR resulted in 138.54 mg GAE g^{-1}. Mixing 80% MOL with 20% PM or GR exhibited 82.62 and 153.23 mg GAE g^{-1} reflecting that GR has higher TPC than PM (Ali *et al.*, 2018; An *et al.*, 2016). The TPC in MHT with 75% MOL and 25% of DM, PM, or CB recorded 77.13, 82.62, and 138.54 mg GAE g^{-1} which may be explained by the high phenolic content in CB powder as mentioned (Abeysekera *et al.*, 2019; Helal *et al.*, 2014). This finding has been similarly remarked with a mix of 70% MOL and MM, DM and CB. Adding 35% MM or AS to 65%, MOL demonstrated that TPC in MA was significantly higher than MMM, which may be clarified by increasing TPC in anise seeds than mint leaves (Mohammad Al-Ismail and Aburjai, 2004; Gülçın *et al.*, 2003; Uribe *et al.*, 2016; Fatiha *et al.*, 2015). In the same context, mixing 40% of GT, AS, or FS with 60% MOL presented higher significant content of TPC in MA than both MGT and MF herbal teas. No significant difference was found between MGT and MF herbal teas at a mixing ratio of 55:45% seems to be that GT and FS had convergent contents of TPC (Salami *et al.*, 2016; Roshanak *et al.*, 2016). The TC ranged from 15.50 to 21.56 mg g^{-1} dw in MF (55:45) and MG (80:20), respectively. *M. oleifera* as a rich source of carotenoids was confirmed (Zhang and Hamauzu, 2004; Saini, Prashanth, Shetty *et al.*, 2014; Saini, Shetty, Prakash *et al.*, 2014). The TC content was higher in MG mixtures even though moringa was mixed with low levels of ginger (15 and 20%), reflecting that carotenoids content in moringa leaves is relatively high. Mixing 75% MOL with 25% of DM, PM or CB recorded 17.99, 19.00, and 18.28 mg g$^{-1,}$ which the high TC may explain in PM leaves (Saini, Prashanth, Shetty *et al.*, 2014; Fatiha *et al.*, 2015; Cappellari *et al.*, 2019). A mixing of GT, AS, or FS with MOL at 40:60% presented higher significant content of TC in MGT than both MA and MF herbal teas. The TC content in MGT (55:45%) was significantly higher than the content in MF (55:45%), which could be explained as a result of the high TC content in green tea (Yang *et al.*, 2009; Roshanak *et al.*, 2016; Santos *et al.*, 2018).

Similar results were recorded for TF and TFL, Table 3. *M. oleifera* leaves contained high levels of flavonoids and flavonols, e.g., quercetin and kaempferol (Amaglo *et al.*, 2010; Coppin *et al.*, 2013; Hadjmohammadi *et al.*, 2013). The TF content ranged from 20.21 to 47.51 mg g^{-1} dw in MF (55:45) and MMM (65:35), respectively. The TFL content ranged from 11.84 to 26.65 mg g^{-1} dw in MF (55:45) and MC (70:30), respectively. MHT with 85% MOL and 15% GR resulted in 31.75 and 21.14 mg QE g^{-1} for TF and TFL contents, respectively. Mixing 80% MOL with 20% PM or GR exhibited 35.95 and 33.22 mg QE g^{-1} for TF and 20.01 and 21.14 mg QE g^{-1} for TF, reflecting that PM has higher TF content than GR, and GR has higher TFL content than PM (Fatiha *et al.*, 2015; Ali *et al.*, 2018; Figueroa-Pérez *et al.*, 2018). This finding has been similarly remarked with a 70% MOL and MM, DM, and CB, confirming that MM has higher TF content than DM and CB. Adding 35% MM or AS to 65%, MOL exuded that TF and TFL in MMM were significantly higher than in MA, which may be clarified by increasing TF and TFL in MM leaves (Hadjmohammadi *et al.*, 2013; Uribe *et al.*, 2016; Figueroa Pérez *et al.*, 2018). Adding 40% of GT, AS, or FS to 60% MOL exhibited that MGT was significantly increased in TF and TFL contents. A high significant difference was found between MGT and MF herbal teas at a mixing ratio of 55:45% in TF and TFL due to the high content in GT than FS (Roshanak *et al.*, 2016; Salami *et al.*, 2016; Santos *et al.*, 2018).

The results of the DPPH-RSA evolution of different MHTs referred to as µmol TE g^{-1} are given in the same table. The result of antioxidants activity (AOA) ranged from 44.51 and 106.66 µmol TE g^{-1} dw for MGT (55:45) and MA (60:40) as similarly reviewed (Naeem *et al.*, 2012; Leone *et al.*, 2015). Mixing 85% MOL with 15% GR resulted in 63.38 μmol TE g^{-1}. The AOA of moringa herbal teas with 75% MOL and 25% of DM, PM, or CB recorded at 54.59, 73.51, and 93.84 μmol TE g^{-1} may approve the high TPC in CB powder as mentioned (Helal *et al.*, 2014; Abeysekera *et al.*, 2019). Increasing CB to 30% significantly increased the AOA of CM herbal tea. They were mixing 35 % MM or AS to 65 % MOL improved the AOA of MA herbal tea due to elevated TPC and TF rates in anise seeds (Kunzemann and Herrmann, 1977; Gülçın *et al.*, 2003; Mohammad Al-Ismail and Aburjai, 2004). In the same way, combining 40 % of GT, AS, or FS with 60 % MOL revealed a higher AOA in MA than both MGT and MF herbal teas. A significant difference was found between MGT and MF herbal teas at a mixing ratio of 55:45 appears to be that GT has higher AOA than FS (Yang *et al.*, 2009; Roshanak *et al.*, 2016; Santos *et al.*, 2018).

3.4 Quantification of individual flavonoids in MHTs following acidic hydrolysis

According to previous studies, the flavonoids mainly based on aglycones such as kaempferol, quercetin, catechin, and luteolin are absorbed faster and in greater quantities than their glycoside counterparts *in vivo* (Izumi *et al.*, 2000). As MHTs obviously contained MOL as the main ingredient, kaempferol, quercetin, catechin, and luteolin derivatives can be easily identified following acidic hydrolysis. HPLC analysis following acidic hydrolysis of differently hot extracted MHTs to know the expected bioaccessible flavonoids as stimulated conditions to the gut was carried out; data was illustrated in Table 4. Quercetin and kaempferol contents as flavonols ranged from 4.11 to 8.02 and from 1.76 to 3.71 mg 100 g^{-1} dw in MPM (80:20) and MG (85:15) and MA (60:40) and MG (80:20), respectively. Mixing 80% MOL with 20% PM or GR decreased quercetin and kaempferol. The decreasing in MOL content and increasing DM, PM, and CB indicated continuous decreases in quercetin and kaempferol, reflecting that MOL has higher quercetin and kaempferol content (Coppin *et al.*, 2013; Leone *et al.*, 2015; Ali *et al.*, 2018). This finding has been similarly remarked with a mix of 70% MOL and both DM or CB except for MM, indicating valuable quercetin and kaempferol in MM (Fatiha *et al.*, 2015; Cappellari *et al.*, 2019). Adding 40% of GT or FS with 60%, MOL remarkably increased quercetin content, while only a slight change was noticed in kaempferol content. Remarkable increases were recorded with increasing FS levels confirming that FS has a rich flavonoids content (Kunzemann and Herrmann, 1977; Salami *et al.*, 2016). Catechin as flavanol and luteolin as flavone was also detected in MHTs following the acidic hydrolysis, Table 4. Remarkably, decreasing the MOL level in MHTs demonstrated gradual decreases in catechin and luteolin contents except when MOL was mixed with GT leaves. Mixing of MOL and GT at (60:40 or 55:45) presented 23.87 and 15.81 and 24.85 and 16.21 mg 100 g^{-1} for catechin and luteolin, respectively. This finding confirmed that both MOL and GT are rich in catechin and luteolin contents (El Sohaimy *et al.*, 2015; Santos *et al.*, 2018).

4. Conclusion

Clearly, the production of herbal teas with valuable bioactive content may pose different functional features. Therefore, scaling up to commercial consumption of moringa presents different ways to obtain various functional benefits. The key goal of this work was to provide appropriate and healthy MHTs to consumers. It can be inferred that combining AHs with MOL categorized them into three groups. Strong AHs were approved when added with 15-25% GR and PM, moderate AHs when added with 25-35% DM, CB, and MM, and mild AHs when added with 35-45%, such as AS, MF, and GT. Increasing AHs levels decreased the astringency and Aftertaste and increased the overall acceptability. The finding obtained offers a wide broad selection to consumers depending on acceptability, availability of raw materials, cost-effectiveness, and applicability. Aglycones such as quercetin, kaempferol, catechin, and luteolin were quantifiable in hot extracted MHTs indicating the expected bioaccessibility in the gut. The highlighted nutritional facts in favored MHTs could provide considerable information to food producers and consumers to switch their food choices to healthy and nutritious selections regards daily drinks.

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