Science World Journal Vol. 17(No 2) 2022
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

DEVELOPMENT AND COMPARATIVE EVALUATION OF JUICES FROM SELECTED FUNCTIONAL INGREDIENTS

[1*]Ndife J., [2]Onyeiwu S.C., [1]Ubbor S.C. and [1]Ukor I.C.

[1]Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Nigeria
[2]Department of Food Technology, Kaduna Polytechnic, Kaduna, Nigeria

*Corresponding Author Email Address: jothel2000@gmail.com

ABSTRACT
Immune boosting foods will ensure protection from diseases by reducing risk of infection and ensuring fast healing. The research was aimed at development and comparative evaluation of juices from extracts of functional ingredients. Samples were labeled according to preponderant ingredient as GG (ginger), GL (garlic), TM (turmeric) and LM (lemon). Sample AC with equal amount of ingredients served as control. The juices were subjected to biochemical, antioxidant and sensory evaluation. The result showed physicochemical properties differed significantly ($p<0.05$) among the juices. LM had the lowest pH (3.30) while GL had the highest (3.70). Vitamin A was lowest in LM (6.25 µg/100 mL) followed by AC (7.85 µg/100 mL). Vitamin B-complex ranged from 0.78 to 1.08 mg/100 mL for vitamin B_1, 0.65-0.93 (B_2), and 2.61-3.45 mg/100 mL in B_3. The juices were high in antioxidant activities from the TPC (48.71-60.45 mgGAE/100 mL), DPPH (53.70-63.32%) and FRAP (51.80-65.30%) values. The flavonoids (6.15-10.85 µg/mL) were higher than tannins (4.34-9.56 µg/mL) and alkaloids (3.03-4.94 µg/mL) in the juices. Bacteria counts in the juices were low ($1.1\text{-}1.5\times10^2$ CFU/100 mL) and no coliform and fungi growth were observed. There was positive response (6.90-7.75) in the sensory perception of the juices. The juices have high phyto-nutrients and antioxidant potentials necessary for boosting body immunity that need to be optimized for specific health use.

Keywords: Functional juice, development, antioxidants, phytochemical, sensory.

INTRODUCTION

The acceptance of juice worldwide is premised on its ease of preparation, application and shelf stability. It is consumed for refreshment and vitality. They contain vitamins, minerals, dietary fibers, antioxidants, and bioactive compounds which have invigorating effects on vital organs in the body (Duel and Sturtz, 2010). Their consumption has been reported to contribute to the prevention of degenerative processes, help inhibit cell proliferation and promote cell differentiation (Chow, 2002). Nowadays, food juices could be produced from different plant sources such as roots, bulbs, herbs, leafy vegetables and fruits (Rathnayaka, 2013; Ndife, 2016).

Ginger (*Zingiber officinalis*) is one of the most valued medicinal plants in Ayurvedic and used to treat different kinds of diseases (Omoruyi *et al*., 2021). It contains several therapeutically active plant-derived secondary metabolites of high pharmacological roles such as antioxidant, antimicrobial, cardiovascular protection, anti-inflammatory, glucose lowering and anticancer activities (Ogbuewu *et al.,* 2014). Ginger can help in the treatment of chronic inflammatory diseases such as fatty liver, asthma, cancer and arthritis through anti-inflammatory, immune-regulatory and antioxidative mechanisms (Al-Awwadi, 2017; Chinedu and Jivini, 2019).

Garlic (*Allium sativum*) is an edible bulb herb, with organosulphur components, especially allicin, diallyltrisulfide, and ajoene, which impart antiviral property and boost immunity (Sharma, 2019). Garlic have been shown to exhibit numerous physiological effects such as hypocholesteremic activity, antithrombotic, inhibiting platelet aggregation, antimicrobial activity, and tumor inhibition (Ourouadi *et al.,* 2017; Sharma, 2019). The vitamins, minerals and other phyto-chemicals in garlic have the power to boost the immune system, fight common virus infections and reduce inflammation (Omoruyi *et al.,* 2021; Chinedu and Jivini, 2019).

Turmeric (*Curcuma longa*) is a rhizomatous herbaceous plant of the ginger family, *Zingiberaceae* (Mane *et al.,* 2018). It is a mild spice that enhances the flavour of other spices and foods, and is the base of most curries. It is widely used for the treatment of diabetes, high cholesterolemia, abdominal pains, menstrual disorder, eczema, jaundice, inflammations, cancerous symptoms and as a blood purifier (Arawande *et al*., 2018).
Lemon (*Citrus limonum risso*) is loaded with wide range of health benefits (Russo *et al.,* 2020). They are rich sources of vitamin C, an antioxidant, which helps maintain strong immunity against oxidative damage caused by free radicals. It also acts as enzyme co-factor for hormone production, collagen synthesis and immune potentiation (Zhang and Liu, 2020). Limonene represents 98% of lemon's healing power, it has been shown to increase the activity of macrophages (white blood cells that engulf foreign particles) (Omoruyi *et al.,* 2021). It has a long history as medicine in the treatment of viral flu.

Honey is widely used for its therapeutic effects. It contains carbohydrates primarily fructose, glucose, fructooligosaccharides (Chow, 2002) and many amino acids, vitamins, minerals and enzymes. Honey is a natural immune-stimulator for the human body. It is high in antimicrobial properties (Hussein *et al.,* 2017). Antioxidant capacity of honey is important in the treatment of many diseases derived from its phenolics, peptides and organic acid components (Calder *et al*., 2020; Wu *et al*., 2020).
Juice has the ability to serve as liquid carrier for myriad of bioactive compounds (Duel and Sturtz, 2010). Crops like ginger, garlic, turmeric and lemon with high nutritional and health promoting components could serve as functional juice ingredients (Ndife, 2016; Al-Awwadi, 2017; Russo *et al*., 2020). Scientific studies have shown that these crops can be exploited as immune boosters in treatment of diseases where orthodox medicines appear to have failed due to their negative side effects (Banerjee *et al.,* 2019;

Calder *et al.,* 2020; Omoruyi *et al.,* 2021). Exploiting these plants by blending their extracts would synergize the different health components. Therefore, the intent of this research was to develop an immune boosting juice and evaluate the physicochemical properties, nutritional and sensory qualities.

MATERIALS AND METHODS

Source of raw materials

Ginger (*Zingiber officinale*), Garlic (*Allium sativum*), Lemon (*Citrus limonum risso*), Tumeric (*Curcuma longa*) and honey were purchased from Ahiaeke market, Umuahia in Abia state. All reagents used for analysis were of standard grade. The research was done at the Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Preparation and Production of fruit juice

Modifications to methods described by Ogori *et al.* (2021) was used in the extraction of the juices. Fresh ginger, garlic, turmeric and lemon fruits were sorted to remove damaged and spoilt ones. They were properly washed with portable water, peeled, washed again, cut into small sizes of 3 – 4 mm thick, weighed (500 g each). Their juices were separately extracted with an automatic juice extractor fitted with filters. Different percentages of the extracts were measured into a sterile electronic cylindrical blender (Nutribullet) and 10% honey was added to the mixture followed by 40% portable water. The samples were labeled according to preponderant ingredient; as GG (ginger), GL (garlic), TM (turmeric) and LM (lemon). Sample AC with equal amount of ingredients served as control (Table 1). The mixtures were blended together to obtain a homogenous mixture and pasteurized (FT75 Armfield model) at 80 °C for 10 min. It was allowed to cool for 45 min, filled into sterile labelled bottles, and stored at refrigeration temperature (4 °C), for further analysis.

Table 1: Formulation of Functional Juices (%)

Ingredient extracts	Sample codes				
	AC	GG	GL	TM	LM
Ginger	12.5	20	10	10	10
Garlic	12.5	10	20	10	10
Turmeric	12.5	10	10	20	10
Lemon	12.5	10	10	10	20
Honey	10	10	10	10	10
Water	40	40	40	40	40

Methods of Analyses

Physicochemical Analysis

The pH was determined by the method described by Adubofuor *et al.* (2010). Measurements of the titratable acidity, specific gravity and total soluble solids (TSS) were determined as described by AOAC (2010).

Vitamin Analysis

Vitamins A (Carotenoids), B_1 (Thiamine), B_2 (Riboflavin), B_3 (Niacin) and C (Ascorbic acid), were assayed using spectrophotometric method of Onwuka (2018).

Determination of Antioxidant Properties

The antioxidant properties of the samples were determined by assaying their ferric reducing antioxidant power (FRAP), Diphenol-2-2- picrylhydroxyl (DPPH) activity and total phenolic content (TPC) (Onwuka, 2018)

Phytochemical Analysis

The determination of tannin was carried out using the method described by Onwuka (2018). The alkaloid content was determined according to the method of Joshi *et al.* (2013). And the flavonoid content in the sample was according to the method of Stankovic (2011).

Microbiological Assay

The determination of total bacteria, coliforms and fungi counts of samples were performed by the methods outlined in compendium of methods for the microbiological examination of foods (APHA, 1992),

Sensory Evaluation

The method described by Iwe (2010) was used. The organoleptic properties of the juice samples were evaluated by 20 semi-trained panelists randomly selected from the staff and students of Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike. They evaluated the sensory properties of appearance, taste, aroma, mouth feel and overall acceptability using a nine-point Hedonic scale.

Experimental Design and Statistical Analysis

A completely randomized design (CRD) was adopted. Results of all determinations were expressed as means of duplicate values. Data were subjected to One-way Analysis of Variance (ANOVA) and significant differences were detected using Duncan multiple range test at 95% confidence level ($p<0.05$). An IBM SPSS Statistical package (version 22.0) was used for all statistical analyses.

RESULTS

Physicochemical Properties of Juices

The results of physicochemical properties are presented in Table 2. The pH value differed significantly ($p<0.05$) with values ranging from 3.30 to 3.70. LM had the lowest value (3.30) while GL had the highest value 3.70. However, relative to titratable acidity, the reverse was the outcome such that LM had the highest value (0.82%) while GL and TM had the lowest values (0.65%).

The SG valued varied from 1.02 to 1.05. GL had the lowest value whereas TM had the highest value. There was a significant difference ($P<0.05$) in the specific gravity (SG) of the samples. The result for total soluble solids (TSS) ranged from 7.80% in GL to 9.62% in LM. There was significant difference ($P<0.05$) in the TSS of the samples.

Table 2: Physicochemical Properties of Juices

Sample	pH	SG	TA (%)	TSS (%)
AC	$3.51^c±0.01$	$1.03^d±0.00$	$0.76^b±0.00$	$8.17^d±0.01$
TM	$3.65^b±0.00$	$1.05^a±0.00$	$0.65^c±0.01$	$8.31^c±0.01$
LM	$3.30^e±0.00$	$1.04^c±0.00$	$0.82^a±0.00$	$9.62^a±0.03$
GG	$3.40^d±0.00$	$1.02^e±0.00$	$0.77^b±0.01$	$8.68^b±0.11$
GL	$3.70^a±0.00$	$1.04^b±0.00$	$0.65^c±0.01$	$7.80^e±0.00$

Values are Mean ± Standard deviation for duplicate determinations. Means with different superscript in the same column are significantly different ($P<0.05$).

TA - Titratable Acidity; **TSS** - Total Soluble Solids. **SG** – Specific Gravity
Key: **AC**-Equal extract mix; **TM**-Tumeric; LM-Lemon; **GG**-Ginger; **GL**-Garlic

Vitamin Content of Juices

The result presented in Table 3 shows the vitamin composition of juices produced. Vitamin A value ranged from 6.25 to 11.77 µg/100 mL and were significantly (p<0.05) different from each other. LM had the lowest value (6.25 µg/100 mL) followed by AC (7.85 µg/100 mL). The Vitamin B-complex ranged from 0.78 to 1.08 mg/100 mL for vitamin B_1, 0.65-0.93 mg/100 mL for vitamin B_2 and 2.61-3.45 mg/100 mL for vitamin B_3. TM had the highest content of vitamin B_1 (1.08 mg/100 mL) while LM had the highest content of vitamin B_2 (0.93 mg/100 mL) and vitamin B_3 (3.45 mg/100 mL). There were significant differences (p<0.05) in vitamin C contents of samples. Vitamin C ranged from 8.82 to 24.79 mg/100 mL. Sample GG had the lowest vitamin C value whereas TM had the highest.

Table 3: Vitamin Content of Juices

Sample	Vitamin A (µg/100 mL)	Vitamin B_1 (mg/100 mL)	Vitamin B_2 (mg/100 mL)	Vitamin B_3 (mg/100 mL)	Vitamin C (mg/100 mL)
AC	$7.85^{d}\pm0.00$	$0.78^{e}\pm0.00$	$0.65^{e}\pm0.00$	$2.61^{c}\pm0.00$	$18.53^{e}\pm0.11$
TM	$11.77^{a}\pm0.02$	$1.08^{a}\pm0.00$	$0.83^{b}\pm0.00$	$2.75^{c}\pm0.01$	$24.79^{a}\pm0.01$
LM	$6.25^{e}\pm0.00$	$1.06^{b}\pm0.01$	$0.93^{a}\pm0.01$	$3.45^{a}\pm0.00$	$20.30^{c}\pm0.00$
GG	$8.82^{a}\pm0.03$	$0.95^{c}\pm0.01$	$0.80^{c}\pm0.00$	$2.84^{ab}\pm0.01$	$8.82^{b}\pm0.03$
GL	$9.81^{c}\pm0.01$	$0.83^{d}\pm0.01$	$0.77^{d}\pm0.01$	$3.05^{ab}\pm0.57$	$19.77^{d}\pm0.04$

Values are Mean ± Standard Deviation for duplicate determinations.
Means with different superscript in the same column are significantly different (P<0.05).
Key: **AC**-Equal extract mix; **TM**-Tumeric; **LM**-Lemon; **GG**-Ginger; **GL**-Garlic

Phytochemical Properties of Juices

Table 4 shows the results of some phytochemical properties of juice samples. The phytochemical values differ significantly (p<0.05) among the samples. The tannin content varied from 4.34 in GL to 9.56 µg/mL (LM). The flavonoid compounds (6.15-10.85 µg/mL) were higher than tannins (4.34-9.56 µg/mL) and alkaloids (3.03-4.94 µg/mL) in the juices. GG (4.04 µg/mL) and other samples had lower alkaloid content (3.03-3.73 µg/mL) compared to the control sample AC (4.94 µg/mL).

Table 4: Phytochemical Properties (µg/mL) of Juices

Sample	Tannins	flavonoids	Alkaloids
AC	$8.18^{a}\pm0.05$	$7.17^{a}\pm0.03$	$4.94^{a}\pm0.05$
TM	$7.07^{b}\pm0.03$	$8.06^{b}\pm0.04$	$3.13^{b}\pm0.03$
LM	$9.56^{c}\pm0.04$	$6.15^{c}\pm0.05$	$3.03^{b}\pm0.02$
GG	$5.25^{d}\pm0.03$	$10.85^{c}\pm0.03$	$4.04^{a}\pm0.05$
GL	$4.34^{e}\pm0.04$	$6.76^{b}\pm0.02$	$3.73^{b}\pm0.03$

Values are Mean ± Standard Deviation for duplicate determinations.
Means with different superscript in the same column are significantly different (P<0.05).
Key: **AC**-Equal extract mix; **TM**-Tumeric; **LM**-Lemon; **GG**-Ginger; **GL**-Garlic

Antioxidant Properties of Juices

The results of antioxidant activities are presented in Table 5. The TPC (Total Phenolic Content) of the samples differ significantly (p<0.05) from each other with values ranging from 48.71 to 60.45 mg GAE/100 mL. GL had the least TPC (48.71 mg GAE/100 mL) whereas TM had the highest (60.45 mg GAE/100 mL).
The DPPH value of the samples ranged from 53.70 to 63.32%. There was significant difference (p<0.05) in the DPPH (1,1-diphenyl-2-picrylhydrazyl) activities of the juices. Sample TM had the highest value (63.32%) followed by LM (59.65%). GG had the highest FRAP value (65.30%) while GL had the least (51.80%). TM (54.31) and LM (53.98) did not differ significantly (p>0.05) from each other as well as AC (52.40) and GL (51.80).

Table 5: Antioxidant Properties of Juices

Sample	TPC (mg GAE/100 mL)	DPPH (%)	FRAP (%)
AC	$52.78^{d}\pm0.07$	$58.76^{c}\pm0.00$	$52.40^{c}\pm0.00$
TM	$60.45^{a}\pm0.00$	$63.32^{a}\pm0.11$	$54.31^{b}\pm0.01$
LM	$58.69^{b}\pm0.13$	$59.65^{b}\pm0.00$	$53.98^{b}\pm1.38$
GG	$56.28^{c}\pm0.04$	$57.24^{d}\pm0.00$	$65.30^{a}\pm0.00$
GL	$48.71^{e}\pm0.01$	$53.70^{e}\pm0.00$	$51.80^{c}\pm0.00$

Values are Mean ± Standard Deviation for duplicate determinations.
Means with different superscript in the same column are significantly different (P<0.05).
TPC- Total Phenolic Content; **DPPH** - 2,2-Diphenyl-1-picrylhydrazyl; **FRAP** - Ferric Reducing Antioxidant Power
Key: **AC**-Equal extract mix; **TM**-Tumeric; **LM**-Lemon; **GG**-Ginger; **GL**-Garlic

Bacteria and Fungi Contents of Juices

The results of microbial content of juice samples are presented in Table 6. The total bacteria counts ranged from 1.1×10^2 to 1.5×10^2 CFU/100 mL. There was no significant (p>0.05) difference in the bacteria counts of juices. Sample TM had the highest bacteria counts (1.5×10^2 CFU/100 mL) while GG had lowest bacteria content (1.1×10^2 CFU/100 mL). There were no detectable growths in coliforms and fungi in the juice samples.

Table 6: Bacteria and Fungi Contents (CFU/100 mL) of Juices

Sample	TBC	TCC	TFC
AC	$1.3\pm0.21\times10^2$	NG	NG
TM	$1.5\pm0.35\times10^2$	NG	NG
LM	$1.3\pm0.25\times10^2$	NG	NG
GG	$1.1\pm0.31\times10^2$	NG	NG
GL	$1.2\pm0.15\times10^2$	NG	NG

Values are Mean ± Standard Deviation for duplicate determinations.
Means with different superscript in the same column are significantly different (P<0.05).
TBC- Total Bacteria Count; **TCC**- Total Coliform Count; **TFC**- Total Fungi Count; **NG**- No Growth
Key: **AC**-Equal extract mix; **TM**-Tumeric; **LM**-Lemon; **GG**-Ginger; **GL**- Garlic

Sensory Evaluation of Juices

The results of the sensory evaluation of juice samples are presented in Table 7. There were significant (P<0.05) differences in the sensory scores among the juices. The scores for appearance of juices ranged from 7.35 to 8.00. The taste of the juices was moderately liked by the panelists (6.45 to 7.95), except TM that was slightly liked (6.45). The aromas of LM (7.85), GG (7.50) and GL (7.00) were more preferred than AC and TM (6.90) that were moderately liked. Juices containing higher proportions of lemon LM (7.65) and ginger GG (7.45) were preferred to other samples in terms of mouth-feel, as LM (7.75) and GG (7.05) were moderately liked. General acceptability scores of juice samples ranged from 6.90 to 7.75. Lemon juice sample (LM) had the highest (7.75) overall acceptance closely followed ginger GG (7.55).

Table 7: Sensory Scores of Juices

Sample	Appearance	Taste	Aroma	Mouth-feel	Acceptability
AC	$8.00^{a}±0.79$	$7.10^{c}±0.64$	$6.90^{c}±0.45$	$6.80^{b}±0.41$	$6.96^{c}±0.31$
TM	$7.35^{b}±0.49$	$6.45^{d}±0.51$	$6.95^{c}±0.51$	$6.30^{c}±0.47$	$6.90^{c}±0.31$
LM	$7.85^{a}±0.37$	$7.95^{a}±0.31$	$7.85^{a}±0.37$	$7.65^{a}±0.49$	$7.75^{a}±0.44$
GG	$7.65^{ab}±0.49$	$7.45^{b}±0.60$	$7.50^{b}±0.51$	$7.45^{a}±0.60$	$7.55^{a}±0.51$
GL	$7.45^{b}±0.60$	$7.10^{c}±0.31$	$7.00^{c}±0.32$	$6.95^{b}±0.22$	$7.05^{c}±0.22$

Values are Mean ± Standard Deviation for duplicate determinations.
Means with different superscript in the same column are significantly different (P<0.05).
Key: **AC**-Equal extract mix; **TM**-Tumeric; **LM**-Lemon; **GG**-Ginger; **GL**-Garlic

DISCUSSION

The pH of juices were low and would be regarded as acidic. The pH range would be dependent on the component ingredients used in the production (Table 2). Low pH range (4.82-4.99) was also reported by Adubofuor *et al.* (2010), and 3.23-4.08 by Ndife *et al.* (2013) for different brands of fruit juices. The results obtained were within standard stipulated range (2.00-5.00) for fruit and vegetable juices (SON, 2008). Fruit juices generally have low pH because they are comparatively rich in organic acid. More so, lemon is rich in citric acid (Tasnim *et al.,* 2010; Russo *et al*., 2020) and may have significantly influenced the acidity of sample LM. This reverse was also observed in the values of titratable acidity by Ndife *et al.* (2013) and Ohwesiri *et al.* (2016). This indicates that, increase in titratable acidity reflects a decreased pH. The titratable acidity determines the acid taste in the juice whereas the pH determines its susceptibility to microbial spoilage, making the food safer for human consumption. The SG value is useful because it allows access to molecular information in a non-invasive way (Mohammed and Ali, 2015). The different juice formulation was observed to influence the specific gravity of the juice samples, by influencing their molecular weights. The values for total solids obtained in this study were lower than 11.75–17.53% for 100% pineapple juice reported by Ohwesiri *et al.* (2016) but within the values 7.22–9.28% for cocktail juices reported by Adubofuor *et al.* (2010) and 5.50–11.80% for different brands of orange juice samples reported by Ndife *et al.* (2013). TSS was highest in LM than in other samples which corresponds with reports from Nelofer *et al.* (2015). The variations observed could be attributed to the blends of different fruit types and ingredients.

The high vitamin A content of the juices (Table 3) will help contribute to the recommended daily intake of 600-1000 μg/day for adults when consumed (Wardlaw, 2004; Ndife *et al.,* 2013). Vitamin A, is an essential fat-soluble vitamin, whose functions include aiding eye vision, skin, bone and red blood cell formation, reproduction, growth and development and immune function (Wardlaw, 2004). Vitamin B_1 has been shown to limit Mycobacterium tuberculosis by enhancing innate immunity (Wardlaw, 2004). Vitamin B_2 (Riboflavin) presence in the juice would contribute towards keeping healthy blood cells (Wardlaw, 2004). Vitamin B_3 is a precursor for enzyme co-factors that assist in their work as catalyst in body metabolism (Wardlaw, 2004). The vitamin C content obtained was lower than the range (23.01-45.57 mg/100 mL) reported by Ndife *et al.* (2013) for commercial juice samples. Vitamin C plays several antioxidant roles and possesses several immune boosting benefits (Edem and Miranda, 2011). The highest value recorded for TM suggests it has potential to deliver the beneficial health properties of vitamin C compared to other samples. Vitamin C also contributes to food stability and appearance (Tasnim *et al*., 2010; Ndife, 2016). The juice samples may be considered as good sources of these vitamins.

In large amounts tannins inhibit the activities of trypsin, amylase and lipase digestive enzymes, decrease dietary protein and iron absorption (Ndife, 2016). Tannins have also been reported to possess antioxidant properties, help blood clotting and stabilize blood pressure (Ndife, 2016; Edem and Miranda, 2011). The tannin values of the juices could be considered moderate to perform health functions. Increased proportions of ginger GG (10.85 μg/mL) and Tumeric TM (8.06 μg/mL) in the juice samples resulted in higher flavonoid contents. Flavonoids from several plant sources exhibit free radical scavenging activity and protection against oxidative stress (Xu and Chang, 2007; Ndife, 2016). Compared to the juice samples, Arawande *et al.* (2018) also reported higher values of alkaloids in water extractives from ginger (16.62%) than turmeric (3.30%). Foods containing alkaloids and flavonoids possess diuretic, antispasmodic, anti-inflammatory and analgesic effects (Duel and Sturtz, 2010; Ndife, 2016). The juices phytonutrients will help improve well-being when consumed

Notably the TPC levels of the samples were appreciably high and are likely to confer beneficial health roles (Table 5). Phenols are one of the major groups of non-nutritive dietary components that have been associated with the inhibition of cancer, atheriosclerosis, as well as ameloriating age-related degenerative brain disorder (Chang *et al*., 2002; Xu and Chang, 2007). According to Chang *et al.* (2002), polyphenolic compounds have inhibitory effects on mutagenesis and carcinogenesis in human when up to 1.0 mg is ingested daily from diets rich in fruits and vegetables. The ability to inhibit DPPH was appreciably high for all samples (53.70-63.32%). Higher DPPH value indicates higher antioxidant potential. Juice with higher proportion of garlic exhibited lower antioxidant activities (DPPH and FRAP values) compared to those containing higher portions of ginger, lemon and turmeric. The results suggest that the samples are capable of scavenging free radicals and can reduce the risks of cancer and chronic diseases (Ferreira *et al.,* 2007; Ndife, 2016; Onwuka, 2018). The variation in values could be attributed to the constituents of bioactives in the raw materials. The antioxidant properties of the samples is in agreement with the report by Wern *et al*. (2017) on the Redox potential of juices. Reducing power is an indication of the potential of the juices to serve as systemic protectant against oxidation and free radical damages in the cells.

The microbial quality of juice samples showed that the total bacteria counts were low (< $1.5×10^2$ CFU/100 mL). Similar low count ($1.2\text{-}5.2×10^2$ CFU/100 mL) was reported by Ndife *et al.*

(2013) in commercial fruit juices. The values were below the maximum bacteria limit (< 2.0×10^2 CFU/100 mL) specified by Nigerian standards organization (SON, 2008) for commercial fruit juices. The low pH exhibited by the juices is critical to the survival of microbes and will ultimately affect their shelf stability (Ezeama, 2007). There were no observable coliform and fungi growths in all the juice samples. This eliminates the possibility of faecal contamination in the samples, which is a pointer to good manufacturing and handling practice (Ezeama, 2007). The juices are fit for human consumption as the value range is below the maximum limit (10^3 CFU/100 mL) for total bacteria counts, considered safe for commercial juices, by Codex standards (ICMSF, 1998).

From the panelists assessment (Table 6), TM with higher turmeric content, had the lowest appearance score (7.35), probably due to its bright yellowish colour, besides the control sample (AC) whose appearance was liked very much (8.00), the rest of the samples were moderately liked (7.35-7.85). This suggests the blending of multiple fruits did not negatively affect the appearance of the juices. Panelist's preferences for juices containing higher proportions of lemon LM and ginger GG in taste and mouth-feel, could be due to their familiarity with these ingredients. Juice with higher proportion of lemon (LM) had the highest acceptance score (7.75), followed by sample GG (7.75). Sensory attributes of juices are important quality parameters on which the consumer preference depends.

Conclusion

This work was aimed at the development and evaluation of a functional juice. The results obtained for the antioxidant, physicochemical, phytochemical and vitamin properties showed significant variation relative to the proportion of individual ingredients. Functional juice containing higher proportion of lemon had better physicochemical properties. Those containing tumeric contain higher quantity of vitamin A, vitamin B1 and vitamin C. Juice with higher proportion of tumeric possess higher antioxidant activities relative to TC and DH activities. The phytochemical properties were appreciably low in all the sales. Sensory perception showed that functional juice containing higher proportion of lemon was best accepted.

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