

PREPARATION AND EVALUATION OF THE PHYSICOCHEMICAL AND STABILITY PROPERTIES OF THREE HERBAL TEA BLENDS DERIVED FROM FOUR NATIVE HERBS

^{1,2} Philip F. Builders, ¹Boma B. Mohammed, ¹Yahaya Z. Sule

¹Department of Pharmaceutics and Industrial Pharmacy Kaduna State University

²Department of Pharmaceutical Technology and Raw Material Development, National Institute for Pharmaceutical Research and Development, Abuja Nigeria

ABSTRACT

Herbal teas consist of mono and sometimes poly-herbal recipes of herbs with acclaimed health benefits which are often brewed as infusion or decoction. Three variants of poly-herbal teas containing *Herbiscus sabdariffa*, *Moringa oleifera*, *Citrus limon*, and *Zingiber officinale* were prepared and evaluated for their physicochemical and stability properties. Intrinsic physicochemical properties that include organoleptic, ash value, pH of brew solutions, extractive matter as well as non-intrinsic properties such as moisture content, flow and particle size of granules and dust leak from teabags were determined. Also, the effects of stressful storage conditions on some physicochemical properties were evaluated. The different tea blends showed remarkable differences in their physicochemical properties. The products also showed discrepancies in stability parameters such as appearance, pH of the brew and antioxidant properties when stored under different conditions. In all, the herbal tea showed good physicochemical and stability properties that are characteristic of a good finished herbal product.

Keywords: Poly-herbal tea, herbal tea bags, physicochemical properties, stability

E-mail Address: philsonsky@yahoo.com

INTRODUCTION

The use of herbal medicine is an age-long system of healthcare which is deeply enshrined in the culture of Africans and many other peoples of the world. In time past people have relied on herbs as the primary healthcare system with much success. Despite modernization and the proliferation of the conventional healthcare system some people still show personal preferences for herbal medicine. Formulating

herbal recipes into tea bags will afford a convenient and safe use of these herbs.

In recent times there has been an apparent upsurge in the popularity and use of herbal teas (1, 2). This corresponds with the contemporary global increase in the popularity and use of herbal medicines (3). Herbal teas therefore belong to a rapidly expanding market of *wellness beverages* (4, 5).

The classical tea is an infusion derived from the leaves and/or other aerial parts of *Camellia sinensis*. Herbal teas are generally infusions or decoctions of mono- or poly-herbal recipes brewed from herbal materials and are often used for their acclaimed health benefits as compared to the aroma, flavor and caffeine stimulant boost of the brew of *C. sinensis* (6, 7). The herbal materials may consist of one or more botanical parts such as leaves, fruits, stems, roots, barks etc. Although they are referred to as *tea* they are nevertheless technically not the classical tea but *herbal materials* (8). These herbal medicines are only officially allowed to be called *tea* only if the name of the plant is included before the word *tea* to distinguish them from the classical tea obtained from *C. sinensis*. Herbal teas often do not contain caffeine (9). They are often used for their therapeutic and/or nutritional benefits, depending on their indication or folk medicinal claims (10, 11).

In Nigeria, there are numerous herbs with acclaimed nutritive and medicinal benefits that are prepared as infusions and decoctions for traditional home use. Among such herbs are *M. oleifera*, *H. sabdariffa*, *Z. officinale* and *C. limon*. These herbs are well known in Nigerian and constitute household condiments in several folk delicacies and beverages (12). Brews derived from their decoctions and infusions are widely consumed as herbal teas for their

nutritive and medicinal benefits. This thus serves as the impetus to prepare and characterize poly-herbal tea blends derived from known folk recipes containing these herbs. The physicochemical properties and any changes which may occur in storage especially under stressful environmental conditions are expected to affect their stability and safety. The aim of this study, therefore, is to prepare and evaluate the physicochemical and stability properties of the different blends of poly-herbal teas derived from the folk recipe containing *M. oleifera*, *H. sabdariffa*, *Z. officinale* and *C. limon* by using simple conventional techniques.

MATERIALS AND METHOD

MATERIALS

Buffer tablets 4, 7 and 9 and silica gel, were obtained from Sigma-Aldrich, Germany. Empty tea bags were purchased from Jumia online trading company. *Hibiscus sabdariffa* dry calyces, *Zingiber officinale* rhizome, and *Citrus limon* fruits were bought from the Kaduna central market. *Moringa oleifera* leaves were collected from a farm in Abaji, Abuja.

METHODS

Collection and Processing of Herbs

Z. officinale: The fresh rhizomes were bought from the open market in Kaduna. The rhizome was scrapped to remove sand clumps, rotten and fibrous sections. The ginger was washed several times with a copious amount of potable water. This was then cut into small sizes of about 2 mm

length with a kitchen knife (13, 14). The cut pieces of rhizome were then pulverized with a kitchen blender (Kenwood, Japan). The wet mass of the rhizome pulp was dried and screened through a sieve of 1 mm mesh size. The dry powder was then packed in a waterproof bag and stored in a cool dark place until used.

M. oleifera: The fresh leaves of *M. oleifera* were then pulverized while still wet with a kitchen blender (Kenwood, Japan). The wet mass of the calyces was then dried and then screened through a sieve of 1 mm mesh size. The powder was then packed in a waterproof bag and stored in a cool dark place until used.

C. limon: The fruits of *C. limon* was bought in Kaduna Central Market. The fruits were washed with copious quantities of water. Then the juice was extracted using a manual hand extractor and used as freshly prepared.

Formulation of herbal tea

Quantities of appropriately processed herbs (*H. sabdariffa*, *M. oleifera*, and *Z. officinale*) required to produce 50 tea bags were weighed out into a large porcelain mortar such that each tea bag contains 5 g of the mixture of herbal materials and 3 mL of the binder solution (2 % w/v Acacia solution) as presented in Table 1. The mixture was massed in the mortar and passed through the sieve. The wet granules were transferred to a hot air oven set at 50 °C and allowed to stay for 10 minutes. The granules were again passed through the same sieve and

dried again for 20 minutes. The dry granules were then packed in a polythene bag, stored in a cool dry place until used for further analysis, and some dispensed into the tea bags and appropriately sealed.

Physicochemical evaluation

Organoleptic properties

The color, odor and taste of the tea brews were evaluated: A 5 g quantity of the dry herbal tea products was placed in a Petri dish. A panel of six assessors was co-opted to evaluate the colour, smell, taste and texture of the tea granules (15).

Ash value

The International Organization for Standardization (ISO) 1575:1987 methods for determination of total ash in tea reviewed and confirmed in 2015 was used (16). Five teabags were randomly selected from each formulation and the content emptied into a large Petri dish. A 2 g quantity of the herbal material was weighed out into a crucible which has initially been heated to $105 \pm 2^\circ\text{C}$ for 5 min and placed in a desiccator until use. The crucible containing the herbal material was then incinerated. The heating temperature was $525 \pm 25^\circ\text{C}$. The crucible was allowed to cool before the weight was determined. Then it was again heated for 30 min and reweighed. This was repeated twice until a constant weight was obtained. The percentage of ash value was determined using Equation 1.

$$\% \text{ ash value} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad \dots 1$$

where W_1 = weight of ash and crucible; W_2 = weight of granule and crucible; W_3 = weight of crucible.

Moisture content

The World Health Organizational method indicated for quality control of medicinal plant materials was adopted (17). Five teabags were randomly selected from each formulation and the content emptied into a large Petri dish. A 3 g quantity of the herbal material was weighed out into an evaporating dish crucible which has initially been heated to 105 ± 2 °C for 5 min and placed in a desiccator until use.

The evaporating dish containing the granules put in an oven maintained at 105 ± 2 °C, the crucible was removed every 30 min and weighed until no change in weight was obtained over two consecutive readings. This was repeated three times. The percentage of moisture content was determined using Equation 2.

$$\% \text{ moisture content} = \frac{C_2 - C_3 \times 100}{C_2 - C_1} \quad \dots 2$$

where: C_1 = weight of the empty evaporating dish

C_2 = weight of crucible + sample before heating

C_3 = weight of crucible = sample after heating.

Extractive matter

A tea bag corresponding to 5 g of the herbal tea for each formula blend was brewed using

250 mL of hot boiling potable water (≈ 100 °C) in a 250 mL beaker flask. The water containing the tea bag was allowed to stand for 24 h with intermittent stirring. A 20 mL quantity of the brew was transferred into a pre-weighed porcelain dish and the water evaporated on a water bath set at 100 ± 2 °C. The porcelain dish was then transferred into a hot air oven set at 50 ± 2 °C and allowed to stay for 1 h. The percentage of the soluble extractive matter was calculated with reference to the dry weight of the sample without the empty bag (18).

pH of brew

A tea bag corresponding to 5 g of the herbal blend was brewed using 250 mL of hot boiling water (≈ 100 °C) in a 250 mL conical flask. The brew was allowed to cool to 27 ± 2 °C. The pH of the brew solution was determined using a digital pH meter (SPER Scientific, China) (19). The brew was stored in a refrigerator at ≈ 5 °C and the pH determined weekly for a four week period.

Dust leak

Two tea bags of the products were selected at random, weighed and placed in a friability tester. The machine was operated for 4 min to undergo the abrasive fall. After the expiration of the 4 min, the tea bags were dusted and weighed.

The percentage leak was evaluated using the formula:

$$\frac{W_1 - W_2}{W_1} \times 100 \quad \dots 3$$

where: W_1 is the initial weight before the leak test W_2 is the weight after the test.

Particle size analysis of herbal tea granules

A 50 g quantity of the granules of each formulation was transferred to a set of sieves mounted on a sieve shaker (Jin-Ling Shang, China). The sieves were arranged in descending order: 0.9 mm, 0.45 mm, 0.28 mm, 0.18 mm, 0.15 mm and pan collector. The vibration was set for 10 min. After the vibration, the granules retained in each sieve and the collecting pan were weighed and recorded. This evaluation was done three times. The data was collected and recorded as particle oversize (20).

Flow properties of granules

The angle of repose: The static angle of repose (a) was measured according to the fixed funnel and free-standing cone method (20). A 50 g quantity of powder was transferred into a funnel of 1 cm orifice. The funnel was clamped 10 cm from the base (such that the funnel neck tip was 10 cm from the flat surface). The tip of the funnel neck was closed with a finger until all the granules have been transferred. The granules were then allowed to flow through to the surface. When all the granules had completely drained, the height and the diameter of the granule mound on the surface was measured and recorded. This was repeated three times.

The angle of repose was then calculated using the formula:

$$\tan \Theta^\circ = 2H/D \quad \dots \dots 4$$

where: Θ° = angle of repose, H = height and D = diameter.

Bulk and tapped densities: The volume occupied by 50 g of each of the granules was determined using a 200 mL graduated measuring cylinder. The tapped volume which corresponds to the final volume of consolidation after tapping with an automated tapping machine (Stampfvolumeter, STAV 2003JEF, Germany) was determined. The bulk (V_o) and tapped (V_T) volumes were evaluated (20).

The bulk and tapped densities were calculated as the ratio of weight to volume (V_o and V_T , respectively) as presented by Equation 5:

$$\text{Mass (g)/Volume (} V_o \text{ or } V_T \text{)} \quad \dots \dots 5$$

Compressibility index: The Compressibility index (CI %) was extrapolated from the bulk and tapped densities using Equation 6:

$$\text{Compressibility index (\%)} = \frac{PT - P_o}{PT} \times 100 \quad \dots \dots 6$$

Stability studies

The effect of storage on the pH of tea brew: storage in the refrigerator at 0 °C

A tea bag corresponding to 5 g of the herbal blend was brewed using 250 mL of hot freshly boiled water ($\approx 100^\circ\text{C}$) in a 250 mL conical flask. The brew was allowed to cool to room temperature ($\approx 27^\circ\text{C}$). The pH of the brew solution was determined using a digital pH meter (SPER Scientific, China). The brew was

stored in a refrigerator ($\approx 5\text{ }^{\circ}\text{C}$) and the pH was determined weekly for four weeks.

The effect of storage of teabags on the pH of tea brews

Six teabags of each formula were divided into two groups. Each three of the herbal tea variants were selected and stored in the photostability chamber while the other three were stored in a conducive home environment (cool dark home kitchen cupboard) for 12 weeks. At the end of this period, the teas were each brewed using 250 mL of hot freshly boiled water ($\approx 100\text{ }^{\circ}\text{C}$) in a 250 mL conical flask. The brew was allowed to cool to $27\pm 2\text{ }^{\circ}\text{C}$. The pH of the brew solution was determined using a digital pH meter (SPER Scientific, China).

The Effect of storage condition on the DPPH free radical scavenging effect of herbal tea brew

Three tea bags of each of the sample formulas were selected and stored at ambient temperature in a cool dark place and in a photostability chamber for 12 weeks. At the end of this period, each sample of the teas was emptied into a 250 mL beaker and mixed, after which a 1 g quantity was weighed into a sample bottle and 20 mL of ethanol added. The mixture was allowed to stand with continuous shaking on a shaker for 24 h. Radical scavenging activity of the ethanol extract of the herbal tea samples against stable 2,

2 diphenyl 2 picryl hydrazyl hydrate (DPPH) was determined by the slightly modified method of Brand-Williams *et al.* (21). A 0.1 mL of the stock solution (equivalent to 0.1 %) was transferred into a screw-capped test tube with a micropipette, 1 mL quantity of freshly made 1 mM of DPPH ethanol solution was added and made up to 10 mL with ethanol. The mixture was shaken and allowed to stand for 30 min in the dark. The absorbance of the mixture was then determined at 517 nm using a UV spectrophotometer. This was also done for the same concentration of ascorbic acid.

The experiment was carried out in triplicate. Radical scavenging activity was calculated by the following formula.

$$\% \text{ Inhibition} = [(A_B - A_A)/A_B] \times 100 \quad \dots \dots 7$$

where: A_B = absorption of blank sample and A_A = absorption of test extract solution.

2.2.10 Statistical Analysis

Results were expressed as the mean \pm standard error of the mean (SEM).

The data was analyzed using one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Preparation herbs

Preparation of herbs in this context includes washing, drying, milling, sieving, packing and labeling. All these processes are critical to the production of standardized herbal medicine. Attention was given to every aspect of the

preparation processes because overlooking any may result in a defective product. The washing of the *M. oleifera* leaves immediately after collection affords a thorough cleaning of the leaves and prevents it from falling off the stalk as this is a characteristic of this plant.

The wet milling of the various herbs is part of the technique used to ensure faster leaching of extracts of the infusion. The drying in the oven of the initially air-dried materials ensures that the required moisture content necessary for optimal microbial control and stability is obtained. The drying controls moisture content in the various raw materials and ensures that accurate quantities of herbal materials are obtained always. Packaging the dry material in sealable poly-bags helps prevent moisture uptake from the atmosphere and labeling with indelible ink is to ensure proper identification and prevent mix-ups. The prepared raw materials are stored in a cool dark place to prevent any degradation that may be induced by light and heat. By so doing the herbs were maintained in good condition for use (22).

Formulation of herbal tea

The objective of formulating the herbs as tea bags is to present the herbs in a form that is stable, easy to use and acceptable to the user. Formulation evaluations showed good throughput and acceptable products. The herbal blends as presented in leachable tea bags are easy to handle and brew, to produce a palatable herbal tea with an acceptable strong aroma and

colour. The granules particle sizes were also controlled by the length of time and speed of pulverization as well as sieving. The controlled multi-particulate granules effectively controlled the leaching, followability and acceptable bulkiness.

Organoleptic properties of tea granules

The organoleptic properties of the herbal teas are presented in Table 2. The organoleptic properties of the various tea blend were determined by evaluating basic intrinsic properties such as colour, smell, taste and texture. Organoleptic evaluation is a low cost and first-line means of identification and assessment of the quality of herbs and herbal materials using the perceptible senses. Though the assessment and judgment may appear to be subjective they are usually the simplest and rather most accurate means of identification and quality assessment (23-25). The colour, smell, feel and taste of the various tea blends reflect the characteristics of the various components that make up the recipe of each polyherbal blend.

Ash value

Ash value is also called total ash. This is the residue remaining after incineration of the test sample. Ash value helps determine the quality and purity of the powdered herb or herbal material. This parameter is useful in determining the authenticity and purity of the herbal material (25). The ash of most plant materials contains calcium carbonate as its major component, this

constitutes 25 to 45 % of the ash. Other components include potash (≈ 10 %), iron, manganese, zinc, copper and heavy metals. The ash values of the herbal teas are presented in Table 3. The differences in the ash value of the various herbal tea blends constitute an intrinsic property of the herbs that make up the tea.

Moisture content

The moisture content of the herbal teas is presented in Table 3. The moisture content of all the herbal teabags were less than 10 %, which is recommended for effective stable storage (26, 27). The measurement of the moisture content especially for herbal materials and products that will be stored for a long time before use is very important. Moisture content is a quality factor in the storage and preservation of herbs and controls the stability of herbal materials especially with regards to various degradation agents such as bacteria and fungi growth as well as enzymatic activities (28). The moisture content of fresh ginger and *M. oleifera* are up to 89 %, while that of the commercially available *H. sabdariffa* is about 26 % (28, 29). To ensure stability during storage of these herbal materials, effective drying was carried out to reduce the moisture content to below 10 %.

Extractive matter

The water extractive matter relates especially to compounds that can be solubilized and extracted by water, this includes such compounds as sugar, acids and various inorganic compounds,

which may include minerals and salts. The water extractive matter determined for the various herbal teas is presented in Table 3. The variable extractive matter shown by the different herbal teas may be related to the differences in the herbal ingredients that constitute the recipe. Also, the high extractive matter may be related to the high solubility of the biochemical constituent in water. The relative high extractive matter experienced with water may be the reason for the acclaimed health benefits of *H. sabdariffa*, *M. oleifera*, *Z. officinale* and *C. limon*.

pH of herbal tea brew

pH is an important parameter in food quality and production. Due to the logarithmic nature of the measurement, even small changes in pH are significant. The difference of one pH level, such as pH 3 and pH 2 represents a ten-fold increase in acid concentration; a change of just 0.3 represents a doubling of acid concentration. The pH value of a food is a direct function of the free hydrogen ions present in that food. Most acidic drinks are often characterized by a distinct sour flavor. The pH of the tea brewed with clean potable water is presented in Table 3. The pH varied from 1.6 to 2.04. The pH shows the relative differences in the phyto-constituents of the herbal tea. The teas containing *H. sabdariffa* all showed low pH values, which relates to the intrinsic characteristic pH of *H. sabdariffa*. *Z. officinale* showed relatively higher pH that corresponds to alkaline pH while that of *M.*

oleifera is slightly acid. The lower relative pH values may show the overwhelming effect of certain ingredients in the herbal blends. Though the tea brew solution shows low pH values, it does not cause harm when swallowed, this may be related to the low concentration of hydrogen ions in the solution.

Flow properties herbal tea granules

Although, the different batch samples of the herbal tea used for both the physicochemical and bio characterization was produced using bench top manual hand fill, automation will however be required during large scale production (30). The mixing and tea bag filling processes are among the most important processes that will require automation. Powder flow is a key requirement for such granule production and packaging. The mixing of the component granules and the filling of the herbal tea granules into the tea bag as well as the sealing will require that the materials and products have a good flow. The effective flow of the granules from the hopper into the tea bags or packaging material is very important and determines the weight uniformity of the filled teabags and the packed tea.

The flow properties as determined by the indirect methods by estimating the Carr's compressibility and angle of repose are presented in Table 3.

The bulk and tapped densities are applied to determine the granule compressibility index as

an indirect method for predicting the flow properties of the herbal granules (20). The lower values derived for the bulk and tapped densities for granules (Table 3) are due to the higher bulk volume per unit weight, a property imparted on herbal granules by the individual ingredients of the herbal recipes. Generally, when assessing powder flow with the Carr's compressibility index, values below 15% represent good flow and 15% to 25% represent fair flow, while values above 25% are indicative of poor flow (20). The flow of powders as assessed by the angle of repose is based on the inter-particulate cohesion: values less than 25° are indicative of "very-good flow", whereas values equal and greater than 25° but less than 50° indicate "good flow" while values greater than 50° indicate "poor flow". Thus, the results presented in Table 3, relating to the angle of repose of the herbal tea granules indicates excellent flow since their angle of repose were all less than 25°.

Particle size of herbal tea granules

The frequency of different particle sizes of granules of the herbal tea is presented in Fig. 2. The particle size of the herbal tea granules is very important as this affects other important parameters such as handling and mixing during production, leaching time, leakage of tea powder from the teabags, flow properties of granules and variation of weight of the filled teabags. Particles with sizes less than 0.15 mm are responsible for the fine particles that leak out of the tea bags as fines. Large particles as could be

likened to those of 1 mm and above are more likely to delay the brewing time when infused in water. The results of the particle size analysis corroborate the results obtained for the dust leak from the various herbal teabags. The particle sizes analysis of the different herbal teas shows acceptable content as only a small fraction are in the fine and large coarse particle sizes. The particle size properties of the herbal teas are not intrinsic to the herbal materials but result from the techniques used during processing. Hence the particle size can be modified by changing the methods, equipment and time used for particle size reduction, granulation technique and other related processes.

Leakage of granule fines from tea bags

This test relates to the ability of the herbal tea bags to withstand handling especially during transportation and other events involving vibration and movements. Leakage occurs when very fine particles migrate out through the pores of the tea bags. The leakage of herbal material from tea bags is presented in Table 3. This relates to the amount of material that escape from the pores of the tea bags and lost. The material that is lost relates to the number of fines contained in tea bag packaging. This loss is not an intrinsic property but is dependent on the formulation technology. The exclusion of fines by processes such as the formation of stable granules larger than the size of fines and/or the physical exclusion of the fines will diminish such leakages. This test may be related to the

friability test of tablets. Friability is an official test with a limit of 1%. The low leak values obtained for the various herbal teabags could be attributed to the stable granules and low quantities of fines in the herbal teas' granule formulations.

Stability of herbal tea

The stability of the physical, chemical and functional properties of a product is important for the continuous maintenance of the efficacy and safety of the product until use (31). The purpose of stability testing is to provide evidence of how the quality of the product will vary with time under the influence of a variety of environmental factors such as temperature, humidity and light. The test is most appropriately carried out in the official container or packaging material. The maintenance of the various physical, chemical and functional properties of a product is important to preserve the efficacy and safety of the product. The properties of the herbal tea, such as physical appearance, the color of the brew, pH are affected by the environmental stress factors such as light, high humidity and temperature.

Effect of storage organoleptic properties on the tea brew

The colour of the brew of teas is often characteristic of the herbal material that constitutes the ingredients. The colour also constitutes one of the major attractions to the patronage and consumption of the product. The colour of the three herbal tea blends was similar

(Table 4) despite the differences in the ingredients contained in the recipe. However, the tilt of the colour of the brew towards red reflects the overwhelming colour of *H. sabdariffa*. The red colour is usually intensified when acidic substances such as the juices of *C. limon* is added to it (32, 33). The storage condition of the teabags was shown to affect the colour of the brews. The samples stored at good ambient controlled storage conditions retained the initial colour and appearance of the various teas as compared to those stored under stress conditions.

The effect of storage on the pH of tea brews of the herbal teas

The pH of the herbal tea brews is presented in Table 5. The pH of the poly-herbal teas was determined as one of the intrinsic properties of the products (34, 35). The pH of the various brews showed acidic pH. The differences in the pH of the three herbal teas may be related to the herbal materials that make up the recipe. The low pH of the poly-herbal tea blends is characteristic of the chemical components of the herbs.. The pH of the different herbal tea showed remarkable differences for the batches stored in normal protected storage conditions and those stored under stress conditions in a photostability chamber at 40 ± 2 °C, thus, indicating probable instability when the teas are stored under stress conditions (36). Whereas, there were no remarkable differences between

the pH of the brews obtained immediately after production and those stored at good ambient controlled conditions.

The effect of storage on the DPPH free radical scavenging effect of the herbal teas.

One of the benefits of herbal medicine is its antioxidant properties, which are elicited by some of the bio-chemicals they contain (37, 38). These biochemicals can mop-up oxidative species that often occur as free radicals. The generation and sustenance of free radicals in the body are responsible for various oxidative stresses that are responsible for several diseases. Oxidative stress reflects an imbalance between the systemic manifestation of reactive oxygen species and the body's ability to readily detoxify these reactive intermediates or to repair the resulting damage they cause (39, 40). The antioxidant substances often occur in many beneficial herbs as phenolic compounds such as flavonoids and glycosides. They react directly with reactive oxygen species to prevent them from reaching their biological targets which include various cells that make up important tissues and organs. It has been proposed that one of the major mechanisms by which herbal medicines produce their health benefits is their effective free radical scavenging properties. The anti-oxidant properties of the freshly prepared herbal teabags were evaluated using DPPH radical scavenging activity. The effect of storage conditions on the antioxidant properties of the

various herbs is presented in Fig. 1. The different herbal teas containing different herbs showed differences in their DPPH radical scavenging activity, which reflects also the differences in the type and concentration of the antioxidant compounds. Fig. 1, shows a relatively high antioxidant property as compared to that of ascorbic acid. Though the effective free radical scavenging properties of ascorbic acid were higher than those of the herbal teas, they can be said to be comparable bearing in mind that the herbal teas are derived from prepared herbs. The storage condition has also been shown to have a remarkable effect on the free radical scavenging properties of the herbal teas. There were no remarkable differences between the anti-oxidant effect of the initial product and that stored in good ambient controlled conditions for 12 weeks as reflected by the DPPH radical scavenging activity of the extracts as compared to when they are stored under stress conditions.

CONCLUSION

Three variants of herbal tea containing blends of *H. sabdariffa*, *M. oleifera*, *Z. officinale* and *C. limon* were developed. The different herbal tea blends showed differences in some physicochemical properties. Such remarkable differences were in some of the intrinsic properties such as organoleptic, pH, ash values and anti-oxidant properties as well as non-intrinsic properties such as flow, moisture

content and particle size respectively. All the products showed physicochemical properties that are characteristic of a good finished herbal product. The herbal tea bags also showed discrepancies in stability that is related to the storage condition. The storage of the herbal tea bags under different environmental conditions resulted in changes in certain physicochemical parameters. Storage in a cool dark cupboard and under a stressful condition in a photo-stability chamber showed remarkable differences in the colour of the granules, pH of the brew and the DPPH free radical scavenging activity of the tea granules. The samples stored in the photo-stability chamber showed remarkable signs of deterioration when compared to those stored in a cool dark cupboard. Thus, it is recommended that the products should be stored in a cool dry place away from light.

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Table 1: Ratio of ingredients used in the working formula of the herbal tea blends

Sample	<i>Herbiscus sabderifer</i>	<i>Zingiber officinalis</i>	<i>Moringa oleifera</i>	<i>Citrus limon</i>
1	1	1	0.5	1
2	1	1	1	1
3	1	2	0.25	1

Table 2: Organoleptic properties of tea granules

Sample	Colour	Smell	Taste	Texture
1	Mottled oxblood	Chokky Aromatic	Sour and spicy	Coarse granules
2	Mottled dark green and gray particle	Pungent	Spicy	Coarse granules
3	Mottled dark green and gray with a tint of red particles	Characteristic aromatic	Sour and spicy	Coarse granules

Table 3: Some physicochemical properties of the herbal teas

Sample	Ash value (%)	Extractive matter (%)	pH of brew solution	Moisture content (%)	CI (%)	AR (°)	Dust leak (%)
1	3.0	42.0 ± 1.20	1.73±0.20	9.0	12.57	19.80	0.18 ±0.03
2	4.0	29.8 ±1.32	1.60±0.22	7.3	23.71	20.55	0.35 ±0.01
3	4.5	26.5 ±1.12	2.04±0.22	7.9	19.68	21.60	0.35 ±0.01

Table 4: Effect of storage on the colour of brew

Sample	Colour of brew after production		Colour of brew 12 weeks stored in a cool dry place at room temperature ($\approx 27^{\circ}\text{C}$)		Colour of brew after 12 weeks stored in a photo-stability chamber at 40°C .	
1	Blood red (Turbid)	++	Blood red (Turbid)	++	Blood red (Clear)	+++
2	Blood red (Turbid)	++	Blood red (Turbid)	++	Blood red (Clear)	+++
3	Blood red (Turbid)	++	Blood red (Turbid)	++	Blood red (Clear)	++

Table 5: pH of tea brew stored in the refrigerator at 0°C .

Sample	1	2	3
Week 1	1.73	1.60	3.72
Week 2	1.74	1.60	3.78
Week 3	1.72	1.60	3.78
Week 4	1.71	1.60	3.65

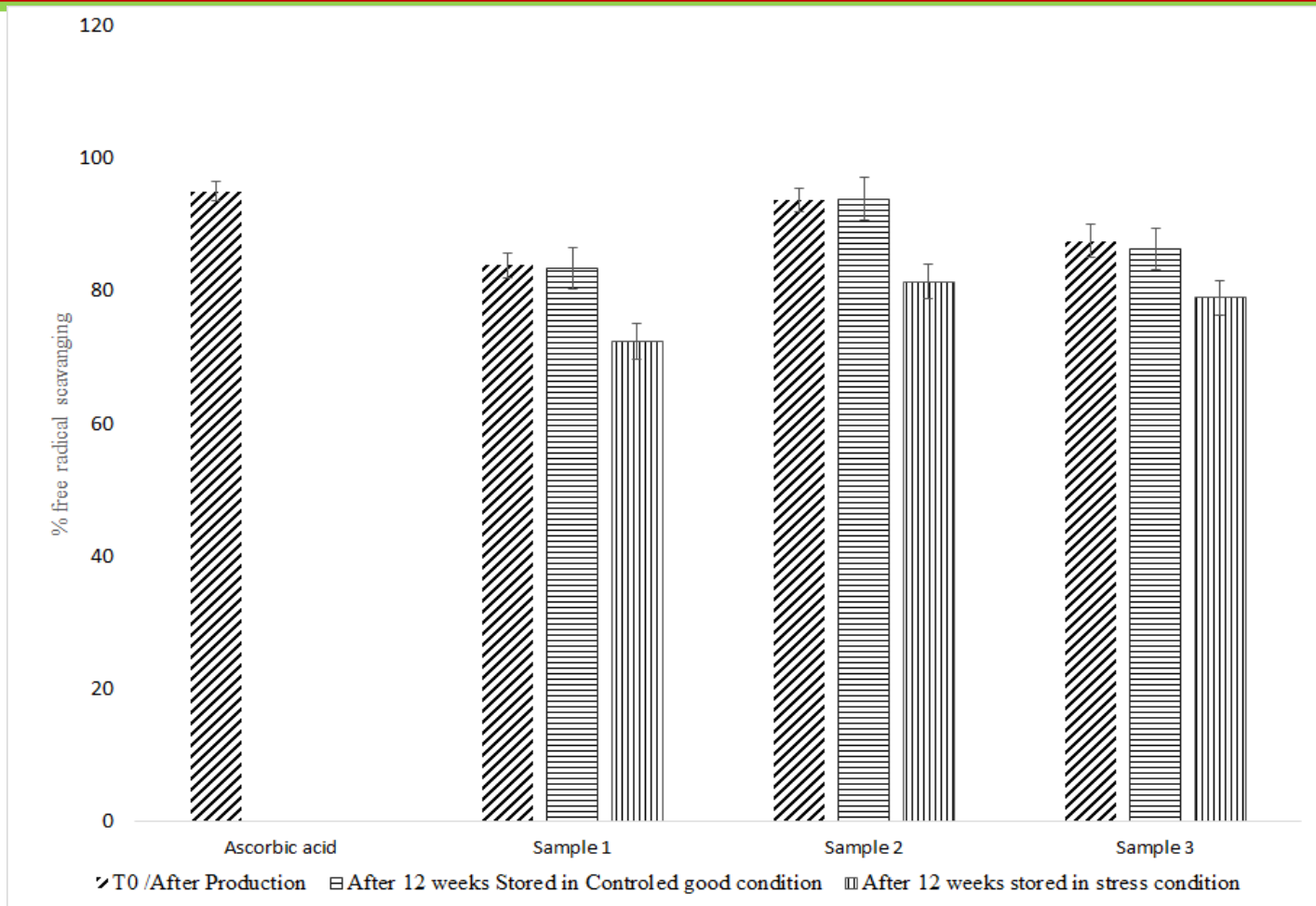


Fig. 1: Effect of storage on the DPPH free radical scavenging effect of herbal teas.