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Fortification of *Hibiscus Sabdariffa* (Roselle plant flower) and *Hyphaene thebaica* (Doum palm) with *Moringa* leaves

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ABSTRACT

Food-to-food fortification (FtFF) is an emerging food-based strategy that can complement current strategies in the ongoing fight against micronutrient deficiencies. *Moringa* leaves are nutritionally very rich in nutrition value. The aim of the research is to fortify *Hibiscus sabdariffa* and Doum palm extracts using *Moringa* leaves extract. *Moringa* leaves, *Hibiscus sabdariffa* and Doum palm samples were collected from Maiduguri Monday Market, Maiduguri and analysed monthly for three months (dry samples) and monthly for three months (wet samples). One hundred (100 mL) of the extract from each of one kilogram (1 kg) of the *Sabdariffa* and Doum palm was fortified with one hundred (100 mL) of the different concentrations (10%, 30% and 50%) of *Moringa* leaves extracts. The samples were prepared and analysed before and after the fortification. Minerals (iron and zinc), protein, fat, moisture, ash, carbohydrates and vitamins (A, B and C) were determined using atomic absorption spectroscopy (AAS), kjedal instrument, soxlet instrument, oven, furnace and HPLC respectively. It was observed that the levels of all the parameters decreased with increase in the concentrations of the *Moringa* leave extract with the exception of carbohydrate in *Sabdariffa* extract sample. It was also observed that the levels of all the parameters in the dry samples were higher than that of the corresponding wet samples with the exception of protein, moisture content, fat (Doum palm), ash (Doum palm) and carbohydrate (*Sabdariffa*) after the fortification. Generally, the fortification power of the different

concentrations of the *Moringa* leave extracts in *Sabdariffa* and Doum palm extracts was in the order 10% > 30% > 50% for all the parameters determined. It was concluded that the *Moringa* was able to fortify both the *Sabdariffa* and Doum palm in terms of the proximate contents (protein, fat, moisture, carbohydrates and ash), minerals (iron and zinc). However, it was not able to fortify the vitamins (A, B and C).

Keywords: Fortification, *Sabdariffa*, Doum palm, *Moringa* Leaves

INTRODUCTION

While substantial reductions in the worldwide prevalence of undernourishment (the percentage of the population without regular access to adequate calories) were made over the period 2005 to 2015. Since 2015 there has been no real improvement, and the number of hungry people in fact increased to 822 million from 785 million in 2015 [1]. The 2019 global hunger score was 20, with average scores as high as 29 for south Asia and 28 for sub-Saharan Africa [2]. Globally, there are 151 million stunted and 51 million wasted children [3]. Food-to-food fortification is an emerging food-based strategy that can be defined as the addition of micronutrient-dense foods to a recipe (household level) or food formulation (food industry level), or the replacement of micronutrient-poor/antinutrient-rich ingredients, to substantially increase the amount of bioavailable micronutrients, with the aim of improving the micronutrient status of populations where the intake of bioavailable micronutrients is inadequate [4]. FtFF should be rooted in the increased scientific knowledge of nutritional composition and compound interactions affecting nutrient bioavailability which makes the standardized, safe and effective implementation of this food-based strategy possible on a commercial scale.

Despite the limited number of studies, the wide diversity of food-based fortificants currently applied and some contradictory findings, there are some promising fortificants that have been shown to improve the amount of bioavailable iron and zinc and provitamin A from starchy staple foods [4]. *Moringa oleifera* is a plant that is often called the drumstick tree, the miracle tree, the ben oil tree, or the horseradish tree. *Moringa* has been used for centuries due to its medicinal properties and health benefits [5]. It also has antifungal, antiviral, antidepressant, and anti-inflammatory properties [5]. *Moringa* contains many healthful compounds such as vitamin A, vitamin B1 (thiamine), B2 (riboflavin), B3 (niacin), B-6, folate and ascorbic acid

(vitamin C), calcium, potassium, iron, magnesium, phosphorus, zinc [5]. It is also extremely low in fats and contains no harmful cholesterol [5]. The benefits of *Moringa* include protecting and nourishing skin and hair; treating edema, protecting the liver, preventing and treating cancer, treating stomach complaints, fighting against bacterial diseases, making bones healthier, treating mood disorders, protecting the cardiovascular system, helping wounds to heal, treating diabetes, treating asthma, protecting against kidney disorders, reducing high blood pressure, improving eye health, treating anemia and sickle cell disease [5].

The doum palm fruit-dates are edible. In Eritrea its name is *Akat*, or *Akaat* in the Tigre language. The thin dried brown rind is made into molasses, cakes, and sweetmeats. The unripe kernels are edible. The shoots of the germinated seeds are also eaten as a vegetable [6]. In Egypt, the fruit is sold by snack street vendors, and in herbalist shops. It is popular among children, gnawing its sweet yet sour hard fibrous flesh beneath the shiny hard crust. Occasionally, its pulp is roasted with sugar and made into a cold summer drink, similar to how Carob drink is made in Egypt. In Diu, Una and Saurashtra region of Gujarat (India), the tree is known as *Hoka Tree* and the red ripe edible fruit is known as *Hoka*. In the northern part of Nigeria, among the Hausa people, it is known as *Goruba*. In south-eastern Niger, its fruit pulp is known as *bri* and a traditional well-known millet pancake is made with this pulp as seasoning, called *massan bri*. A commercial drink in Niger, called *Torridité Glacée*, is made from this fruit, somewhat reminiscent in taste of ice coffee or milk chocolate [7]. In India, *Hibiscus Sabdariffa* plant is primarily cultivated for the production of bast fibre used in cordage, made from its stem [8]. In Nigeria, the calyx of the plant is used in making a beverage commoly called *Zobo* in Nigeria [9]. The fibre may be used as a substitute for jute in making burlap *Hibiscus*, specifically roselle, has been used in folk medicine as a diuretic and mild laxative [10]. The red calyces of the plant are increasingly exported to the United States and Europe, particularly Germany, where they are used as food colourings. It can be found in markets (as flowers or syrup) in places, such as France, where there are Senegalese immigrant communities. The green leaves are used like a spicy version of spinach. They give flavour to the Senegalese fish and rice dish *thieboudienne*. Proper records are not kept, but the Senegalese government estimates national production and consumption at 700 t (770 short tons) per year [11].

Marius et al. [12] designed a fermented sorghum porridge food-fortified with *Moringa* leaf powder and baobab fruit pulp. Results (expressed in dry weight) indicate that food fortification increases significantly (p<0.05) fermented sorghum porridge iron content from 7.3±0.2 mg/100 g to 88.4±1.2 mg/100 g, zinc content from 88.2±3.8 mg/100 g to 202.4±3.1 mg/100 g. Soluble minerals of the porridge after fortification increase significantly (p<0.05) from 0.3±0.0 mg/100 g to 1.8±0.1 mg/100 g for iron, from 0.4±0.1 mg/100 g to 4.2±0.2 mg/100 g for zinc. Food fortification using *Moringa* leaf powder and baobab fruit pulp could be a good alternative for micronutrient deficiency alleviation.

Fermented dairy products are known for their many positive effects on human health and are consumed worldwide. The supplementation of food with plant extracts as sources of valuable nutritional compounds has recently gained a lot of attention. Yoghurts enriched with *Moringa* extract (ME) (1, 3 and 4%, *v*/*v*) were produced and compared to a control yoghurt without ME. In all samples, mineral contents were determined. Yoghurts with ME addition had a higher mineral content and gained a better sensory score when compared to the control sample [13].

Street-vended foods are cheap, readily available and have been currently identified as possible means for micronutrient fortification in an effort to prevent malnutrition in developing countries. The effect of enriching street-vended Zobo drink (*Hibiscus Sabdariffa*) with turmeric (*Curcuma longa*) was studied to assess the potential to increase health-supporting properties for its consumers. Dried Zobo (*H. Sabdariffa*) calyces were purchased from Dutse market, Abuja, Nigeria. Turmeric roots were purchased from Omuooke-Ekiti market, Ekiti State, Nigeria. Two processing methods were tested: boiled turmeric root in Zobo and addition of fresh turmeric paste to Zobo in different concentrations. Vitamin C in turmeric-fortified Zobo ranged from 496-725 µg per 100 mL while micronutrients ranged from 10.9-14 mg L^{-1} and 2.19-2.67 mg L^{-1} for iron and zinc, respectively. Folic acid, vitamin C and iron showed the highest amounts in the 2% boiled turmeric Zobo samples. Consumption of a typical one serving of 500 mL (representative packaged bottle size of Zobo drink by the street vendors in Nigeria) of turmeric-fortified Zobo would contribute 63-88% DV and 18-23% DV of iron and zinc. Overall, fortification with boiled turmeric improves the antioxidant and nutritional quality of 'Zobo', specifically regarding vitamin C and iron [14].

Kehinde and Augustie [15] studied the proximate and phytochemical contents of Zobo drinks flavored fortified with pineapple and watermelon. Dry calyces of H. *Sabdariffa* (Zobo) leaves were obtained from Lafenwa market in Abeokuta, Nigeria and were identified by a botanist. The results showed that Zobo drinks flavored with pineapple and watermelon was generally higher in proximate and phytochemical contents. It was observed that Zobo drink flavored with watermelon has the highest concentrations of protein (0.91%) and ash (0.79%). Zobo drink flavored with pineapple was observed to contain the highest concentrations of crude fat (3.04%), crude fibre (0.16%) as well as energy value of 73.12 KJ/100mL. On the other hand, unflavored Zobo drink was highest in moisture (87.33%) and carbohydrate (11.07%) concentrations. This result showed that fortification of Zobo drinks with pineapple and watermelon enhances its nutritional qualities.

The purpose of this research is to increase the nutritional contents of *Sabdariffa* and Doum palm using *Moringa* leaves.

METHODOLOGY

Study area

Maiduguri is the capital and the largest city of Borno State in north-eastern Nigeria, on the continent of Africa. The city sits along the seasonal Ngadda River which disappears into the *Firki* swamps in the areas around Lake Chad [16].

Sample collection

The samples (*Moringa* leaves, *Sabdariffa* and Doum palm) were collected from Maiduguri Monday Market, Maiduguri. The samples were labelled with a unique identification number and transported to the National Agency for Food and Drug Administration (NAFDAC) laboratory, Maiduguri, Borno State, for further analysis. The samples were collected three times in rainy season (dry samples) and three times in dry season (wet samples) for determining the nutritional values of the dry and wet samples and fortification powers (percentage increase or efficiency of the *Moringa* sample). The samples were identified by Professor S. S. Sanusi, Department of Biological Sciences, University of Maiduguri.

Fortification

The *Moringa* leaves (source of iron and zinc, vitamins A, B and C), *Sabdariffa* and Doum palm Samples were dried under shield and ground to powder. One kilogram (1 kg) each of the *Moringa* leaves, *Sabdariffa* and Doum palm powders were weighed into different conical flasks and one litre (1 L) of deionized water was added to each. These were boiled for 5 minutes, cooled and sieved to obtain the extracts. Different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts were prepared by mixing the *Moringa* leaves extracts and water in the ratio of 10 mL to 90 mL (10%), 30 mL to 70 mL (30%) and 50 mL to 50 mL (50%). One hundred (100 mL) of the extract from each of the *Sabdariffa* and Doum palm were added with one hundred (100 mL) of different concentrations (10%, 30% and 50%) of *Moringa* leaves extracts separately [17]. The fortified samples were thoroughly mixed and kept for analysis.

Sample preparation

The samples were prepared for proximate analysis according to the procedure of Association of Official Analytical Chemist (A.O.A.C.) for moisture, ash, fat and crude protein content [18]. For the minerals digestion, the sample (50 ml) was measured into a glass beaker and ten millilitre (10 ml) of concentrated HNO_3 was added and kept on a hot plate for slow boiling. When the volume reduced to 10-15 millilitres, 1M HNO_3 was added and again heated till the volume reduced to about ten millilitres (10 ml) and a clear solution (without any suspension or colour) was obtained. It was then transferred by filtration through filter paper (Whatmann no 41) into a volumetric flask and volume of filtrate was made up to fifty millilitres (50 ml) mark by adding deionised water. The digested sample was kept in poly propylene bottles at room temperature [19].

Sample analysis

The prepared samples were analysed before and after the fortification. Minerals (iron and zinc), protein, fat, moisture, ash, carbohydrates and Vitamins (A, B and C) were determined using AAS, kjedal instrument, soxlet instrument, oven, furnace and HPLC respectively.

RESULTS AND DISCUSSION

Table 1 shows the mean with standard deviation of the results of nutritional values of the samples (*Moringa* leaves, *Sabdariffa* and Doum palm) extracts before the fortification.

Table 1: Nutritional values of Samples (*Moringa* leaves, *Sabdariffa* and Doum palm) extracts before the fortification

Nutritional Contents	Nature of the *Sabdariffa*	*Moringa* Leaves	*Sabdariffa*	Doum palm
Protein (%)	Dry	0.02± 0.09	1.03± 0.01	1.02 ± 0.02
	Wet	0.31± 0.01	0.78± 0.43	0.72± 0.01
Fat (%)	Dry	0.34± 0.11	0.20 ± 0.00	1.05 ± 0.01
	Wet	0.47± 0.01	0.97± 0.21	0.42± 0.00
Moisture (%)	Dry	97.38± 0.69	93.97 ± 0.42	94.72 ± 0.05
	Wet	96.59± 0.01	94.00± 0.21	95.43± 0.06
Ash (%)	Dry	0.44± 0.31	0.76 ± 0.01	0.51 ± 0.01
	Wet	0.50± 0.01	1.00± 0.02	0.99± 0.02
Carbohydrates (%)	Dry	1.82± 0.01	4.04± 0.03	3.21± 0.03
	Wet	2.13± 0.04	3.25± 0.02	2.43± 0.01
Iron (mg/L)	Dry	4.73± 0.14	2.11± 0.14	4.79± 0.14
	Wet	3.03± 0.12	3.79± 0.84	1.68 ± 0.01
Zinc (mg/L)	Dry	2.08± 0.02	1.03± 0.01	2.71 ± 0.07
	Wet	2.36± 0.20	2.48 ± 0.33	1.53± 0.02
Vitamins A (mg/L)	Dry	94.81± 0.09	94.71 ± 0.01	94.39 ± 1.08
	Wet	93.18± 0.44	91.84 ± 0.01	94.19± 0.00
Vitamins B (mg/L)	Dry	95.32± 0.48	93.61 ± 0.01	94.58 ± 0.01
	Wet	94.83± 2.23	92.84 ± 0.56	93.82± 0.03
Vitamins C (mg/L)	Dry	93.74± 0.06	95.44 ± 1.04	95.08 ± 0.05
	Wet	95.17± 1.22	93.19 ± 0.56	93.16± 0.03

Replicate=3 (months)

The results show that the highest value (1.03± 0.01%) of protein was observed in dry *Sabdariffa* sample while the lowest value (0.02± 0.09%) was observed in dry *Moringa* sample. The highest value (1.05 ± 0.01) of fat was observed in dry Doum palm sample while the lowest value (0.20 ±

0.00%) was observed in dry *Sabdariffa* sample. The highest value (97.38± 0.69%) of moisture was observed in dry *Moringa* sample while the lowest value (93.97 ± 0.42%) was observed in dry *Sabdariffa* sample. The highest value (1.03± 0.01%) of ash was observed in wet *Sabdariffa* sample while the lowest value (0.44± 0.31%) was observed in dry *Moringa* sample. The highest value (4.04± 0.03%) of carbohydrate was observed in dry *Sabdariffa* sample while the lowest value (1.82± 0.01%) was observed in dry *Moringa* sample. The highest value (4.79± 0.14 mg/L) of iron was observed in dry Doum palm sample while the lowest value (1.68 ± 0.01 mg/L) was observed in wet Doum palm sample. The highest value (2.71 ± 0.07 mg/L) of zinc was observed in Doum palm sample while the lowest value (1.03± 0.01 mg/L) was observed in dry *Sabdariffa* sample. The highest value (94.81± 0.09 mg/L) of vitamin A was observed in dry *Moringa* sample while the lowest value (91.84 ± 0.01 mg/L) was observed in wet *Sabdariffa* sample. The highest value (95.32± 0.48 mg/L) of vitamin B was observed in dry *Moringa* sample while the lowest value (92.84 ± 0.56 mg/L) was observed in wet *Sabdariffa* sample. The highest value (95.44 ± 1.04 mg/L) of vitamin C was observed in dry *Sabdariffa* sample while the lowest value (93.16± 0.03 mg/L) was observed in dry doum palm sample.

Table 2 shows the nutritional values of *Sabdariffa* before (control) and after (treatments) fortification with different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts.

Table 2: Nutritional values of *Sabdariffa* before (control) and after (treatment) fortification with different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts

Nutritional Contents	Nature of the *Sabdariffa*	Formula			
		Control	Treatment		
		0%	10%	30%	50%
Protein (%)	Dry	1.03± 0.01	0.95± 0.01	0.74± 0.01	0.48± 0.22
	Wet	0.78± 0.43	1.01± 0.04	0.86± 0.51	0.66± 0.23
Fat (%)	Dry	0.20 ± 0.00	0.52± 0.01	0.48± 0.01	0.43± 0.34
	Wet	0.97± 0.21	1.34± 0.03	1.15± 0.41	0.91± 0.23
Moisture (%)	Dry	93.97 ± 0.42	90.98± 0.45	81.58± 6.01	69.83± 0.23
	Wet	94.00± 0.21	90.60± 0.30	81.20± 9.01	69.45± 0.89
Ash (%)	Dry	0.76 ± 0.01	1.12± 0.01	0.97± 0.01	0.78± 0.33

	Wet	1.00± 0.02	1.40± 0.01	1.20± 0.01	0.95± 0.06
Carbohydrates (%)	Dry	4.04± 0.03	6.43± 0.01	12.23± 0.01	28.47± 0.00
	Wet	3.25± 0.02	5.65± 0.67	15.60± 0.41	28.04± 0.00
Iron (mg/L)	Dry	2.11 ± 0.00	6.63± 0.11	6.21± 1.01	5.68± 0.67
	Wet	3.79± 0.84	6.44± 0.31	5.68± 1.01	4.74± 0.22
Zinc (mg/L)	Dry	1.03± 0.01	3.01± 0.01	2.80± 4.01	2.54± 0.44
	Wet	2.48 ± 0.33	4.59± 0.51	4.10± 0.31	3.48± 0.32
Vitamins A (mg/L)	Dry	94.71 ± 0.01	90.02± 0.81	80.56± 2.01	68.71± 5.08
	Wet	91.84 ± 0.01	87.92± 0.71	78.73± 6.01	67.25± 0.01
Vitamins B (mg/L)	Dry	93.61 ± 0.01	89.78± 0.91	80.42± 9.01	68.72± 9.03
	Wet	92.84 ± 0.56	89.19± 0.81	79.91± 2.01	68.30± 5.87
Vitamins C (mg/L)	Dry	95.44 ± 1.04	89.82± 0.91	80.27± 2.01	68.34± 3.90
	Wet	93.19 ± 0.56	89.52± 0.71	80.20± 12.01	68.55± 2.90

Replicate=3 (months), Control= before fortification

It was observed that the levels of fat, ash, iron, zinc, vitamin A, vitamin B and vitamin C in the dry samples were higher than that of the corresponding wet samples with the exception of protein, moisture content and carbohydrate after the fortification. The might be due to the differences in their solubilities in water. It was also observed that the levels of protein, moisture content, fat, ash, iron, zinc, vitamin A, vitamin B and vitamin C decreased with increase in the concentrations of the *Moringa* leaves extract with the exception of carbohydrate. Finally, it was observed that the levels of protein (wet sample), fat, ash, carbohydrate, iron and zinc increase after the fortification while the levels of the moisture content, protein (dry sample) and the vitamins decreased after the fortification. This might be due to the fact that the concentrations of the *Moringa* leaves extract (10%, 30% and 50%) used is not favorable for the vitamin fortification of the *Sabdariffa* and Doum palm extracts.

Table 3 shows the nutritional values of Doum palm before (control) and after (treatments) fortification with different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts.

Table 3: Nutritional values of Doum palm before (control) and after (treatment) fortification with different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts

Nutritional contents	Nature of the Doum palm	Formula			
		Control	Treatment		
		0%	10%	30%	50%
Protein (%)	Dry	1.02 ± 0.02	0.94± 0.00	0.73± 0.01	0.48± 0.05
	Wet	0.72± 0.01	0.96± 0.00	0.81± 0.00	0.63± 0.00
Fat (%)	Dry	1.05 ± 0.01	1.285± 0.03	1.08± 0.08	0.81± 0.02
	Wet	0.42± 0.00	0.85± 0.11	0.76± 0.03	0.66± 0.02
Moisture (%)	Dry	94.72 ± 0.05	91.31± 1.32	81.84± 3.32	70.00± 0.02
	Wet	95.43± 0.06	91.24± 3.33	81.70± 0.02	69.77± 9.02
Ash (%)	Dry	0.51 ± 0.01	0.90± 0.04	0.80± 0.02	0.67± 0.00
	Wet	0.99± 0.02	1.391± 0.03	1.19± 0.10	0.95± 0.02
Carbohydrates (%)	Dry	3.21± 0.03	4.709± 1.05	4.07± 0.22	3.26± 0.08
	Wet	2.43± 0.01	4.32± 0.04	3.83± 0.03	3.22± 0.06
Iron (mg/L)	Dry	4.79 ± 0.00	9.041± 1.03	8.08± 0.09	6.89± 0.09
	Wet	1.68 ± 0.01	4.542± 0.45	4.21± 0.05	3.79± 0.11
Zinc (mg/L)	Dry	2.71 ± 0.07	4.52± 0.33	3.98± 0.02	3.30± 0.44
	Wet	1.53± 0.02	3.74± 0.11	3.43± 0.02	3.05± 0.77
Vitamins A (mg/L)	Dry	94.39 ± 1.08	89.88± 8.02	80.44± 5.02	68.64± 11.07
	Wet	94.19± 0.00	88.98± 6.08	79.56± 7.07	67.78± 12.21
Vitamins B (mg/L)	Dry	94.58 ± 0.01	90.22± 4.44	80.76± 0.09	68.94± 8.07
	Wet	93.82± 0.03	89.63± 6.02	80.25± 0.99	68.52± 4.02
Vitamins C (mg/L)	Dry	95.08 ± 0.05	89.66± 6.02	80.14± 0.06	68.26± 6.09
	Wet	93.16± 0.03	89.51± 1.02	80.19± 6.67	68.546± 7.88

Replicate=3 (months), Control= before fortification

It was observed that the levels of moisture content, carbohydrate, iron, zinc, vitamin A, vitamin B and vitamin C in the dry samples were higher than that of the corresponding wet samples with the exception of protein, fat and ash after the fortification. It was also observed that the levels of all the parameters decrease with increase in the concentrations of the *Moringa* leave extract.

Finally, it was observed that the levels of protein (wet sample), fat, ash, carbohydrate, iron and zinc increase after the fortification while the levels of the protein (dry sample), moisture content and the vitamins decrease after the fortification. This might be due to the fact that the concentrations of the *Moringa* leaves extract (10%, 30% and 50%) used is not favorable for the vitamin fortification of the *Sabdariffa* and Doum palm extracts.

Table 4 shows the fortification power (percentage increase) of different concentrations (10%, 30% and 50%) o the *Moringa* leaves extracts in *Sabdariffa* extract.

Table 4: Fortification Power (Percentage Increase (%)) of different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts in *Sabdariffa* extract

Nutritional contents	Nature of the *Sabdariffa*	Treatment		
		10%	30%	50%
Protein	Dry	-8.06	-28.06	-53.06
	Wet	29.74	9.74	-15.26
Fat	Dry	80.00	70.00	59.00
	Wet	38.45	18.45	-6.55
Moisture	Dry	-3.19	-13.19	-25.69
	Wet	-3.62	-13.62	-26.12
Ash	Dry	47.89	27.89	2.89
	Wet	40.00	20.00	-5.00
Carbohydrates	Dry	59.16	87.55	98.66
	Wet	73.85	90.00	99.54
Iron	Dry	98.00	91.00	85.20
	Wet	69.95	49.95	24.95
Zinc	Dry	96.95	86.61	7.49
	Wet	85.16	65.16	40.16
Vitamins A	Dry	-4.95	-14.95	-27.45
	Wet	-4.27	-14.27	-26.77
Vitamins B	Dry	-4.09	-14.09	-26.59

	Wet	-3.93	-13.93	-26.43
Vitamins C	Dry	-5.89	-15.89	-28.39
	Wet	-3.94	-13.94	-26.44

Various percentages increase were observed for protein (wet sample), fat, ash, carbohydrate, iron and zinc after the fortification while there were various percentages decease for the protein (dry sample), moisture content and the vitamins after the fortification. The percentage increase decreased with increase in the concentrations of the *Moringa* leaves extract while the percentage decrease increased with increase in the concentrations of the *Moringa* leaves extract Generally, the fortification power of the different concentrations of the *Moringa* leaves extracts in *Sabdariffa* extract was in the order 10% > 30% > 50% for all the parameters determined.

Table 5 shows the fortification Power (Percentage Increase) of different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts in Doum palm extract.

Table 5: Fortification Power (Percentage Increase (%)) of different concentrations (10%, 30% and 50%) of the *Moringa* leaves extracts in Doum palm extract

Nutritional contents	Nature of the Doum palm	Treatment		
		10%	30%	50%
protein	Dry	-8.04	-28.04	-53.04
	Wet	33.06	13.06	-11.94
fat	Dry	22.38	2.38	-22.62
	Wet	99.00	81.90	56.90
moisture	Dry	-3.60	-13.60	-26.10
	Wet	-4.39	-14.39	-26.89
ash	Dry	76.27	56.27	31.27
	Wet	40.51	20.51	-4.49
carbohydrates	Dry	46.70	26.70	1.70
	Wet	77.65	57.65	32.65
iron	Dry	88.75	68.75	43.75

	Wet	85.36	75.36	65.36
zinc	Dry	66.75	46.75	21.75
	Wet	72.25	62.25	59.25
vitamins A	Dry	-4.78	-14.78	-27.28
	Wet	-5.54	-15.54	-28.04
vitamins B	Dry	-4.61	-14.61	-27.11
	Wet	-4.46	-14.46	-26.96
vitamins C	Dry	-5.70	-15.70	-28.20
	Wet	-3.92	-13.92	-26.42

Various percentages increases were observed for protein (wet sample), fat, ash, carbohydrate, iron and zinc after the fortification while there were various percentages decease for the protein (dry sample), moisture content and the vitamins after the fortification. The percentage increase decreased with increase in the concentrations of the *Moringa* leaves extract while the percentage decrease increased with increase in the concentrations of the *Moringa* leave extract. Generally, the fortification power of the different concentrations of the *Moringa* leaves extracts in *Sabdariffa* and Doum palm extracts was in the order 10% > 30% > 50% for all the parameters determined.

The samples (*Moringa* leaves, *Sabdariffa* and Doum palm) extracts contain various levels of the proximate contents (protein, fat, moisture, carbohydrates and ash), minerals (iron and zinc) and vitamins (A, B and C) before the fortification. The levels of protein, moisture content, fat, ash, iron, zinc, vitamin A, vitamin B and vitamin C decreased with increase in the concentrations of the *Moringa* leave extract with the exception of carbohydrate in *Sabdariffa* extract sample after the fortification. This shows that 10% concentration of the *Moringa* is the best concentration for the fortification. It was also observed that the levels of fat, ash, iron, zinc, vitamin A, vitamin B and vitamin C in the dry samples were higher than that of the corresponding wet samples with the exception of protein, moisture content, fat (Doum palm), ash (Doum palm) and carbohydrate (*Sabdariffa*). This shows that dry samples are richer in the minerals (iron and zinc) and vitamins (A, B and C) than the wet samples. Generally, this also shows that the wet samples are richer in the proximate contents (protein, fat, moisture,

carbohydrates and ash) than the dry samples of the *Sabdariffa* and Doum palm. Generally, the fortification power of the different concentrations of the *Moringa* leaves extracts in *Sabdariffa* and Doum palm extracts was in the order 10% > 30% > 50% for all the parameters determined. This shows that 10% concentration of the *Moringa* is the best concentration for the fortification. Finally, it was concluded that *Moringa* was able to fortify both the *Sabdariffa* and Doum palm in terms of the proximate contents (protein, fat, moisture, carbohydrates and ash), minerals (iron and zinc). However, it was not able to fortify the vitamins (A, B and C).

The results of the proximate analysis of the preset work is in line with that of Kehinde et al. [15] with the exception of protein which is higher than the present result. The concentration of iron and zinc in the present work is lower than that of idowu et al. [14]. In the present work, the fortification power (or percentage) decrease with increase concentration of the fortificant (*Moringa* extract). However, fortification power (or percentage) in similar study carried out by Lisak [13] increase with increase concentration of the fortificant (*Moringa* extract).

CONCLUSION

The results showed that the samples (*Moringa* leaves, *Sabdariffa* and Doum palm) extracts contain various levels of the proximate contents (protein, fat, moisture, carbohydrates and ash), minerals (iron and zinc) and vitamins (A, B and C) before the fortification. It was observed that the levels of protein, moisture content, fat, ash, iron, zinc, vitamin A, vitamin B and vitamin C decreased with increase in the concentrations of the *Moringa* leave extract with the exception of carbohydrate in *Sabdariffa* extract sample. It was also observed that the levels of fat, ash, iron, zinc, vitamin A, vitamin B and vitamin C in the dry samples were higher than that of the corresponding wet samples with the exception of protein, moisture content, fat (Doum palm), ash (Doum palm) and carbohydrate (*Sabdariffa*) after the fortification. Futhermore, it was observed that the levels of protein (wet sample), fat, ash, carbohydrate, iron and zinc increased after the fortification while the levels of the moisture content, protein (dry sample) and the vitamins decreased after the fortification. Generally, the fortification power of the different concentrations of the *Moringa* leaves extracts in *Sabdariffa* and Doum palm extracts was in the order: 10% > 30% > 50% for all the parameters determined. Finally, it was concluded that the *Moringa* was able to fortify both the *Sabdariffa* and Doum palm in terms of the proximate contents (protein,

fat, moisture, carbohydrates and ash), minerals (iron and zinc). However, it was not able to fortify the vitamins (A, B and C).

It is therefore recommended to try other concentrations of the *Moringa* leaves extracts for the purpose of the vitamins fortification of the *Sabdariffa* and Doum palm extracts.

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