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Evaluation and Chemometric Analysis of the Mineral Profile of Locally Prepared Soups in Minna, Niger State, Nigeria

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ABSTRACT

Minerals are indispensable part of a complete diet for humans. This study was conducted to evaluate the presence of five of these minerals; three essential minerals (Sodium, Calcium, and Potassium), two trace minerals (Iron, and Copper) and a toxic metal (Lead) present in local soups in Minna, Niger State. The samples were purchased locally in triplicates from restaurants in Minna, Niger State. The soups were homogenized, weighed, dried, and then digested with proportionate combinations of HNO_3, H_2O_2 and de-ionized water. The elements were determined using Atomic Absorption and Flame Emission Spectrophotometers. Microsoft Excel and MATLAB/PLS tool box software were used for Chemometrics analysis. Results indicate that *Dahyen kubewa* and *Miyanya kuwa* have prominent content of studied elements with relative higher values making them good source of essential mineral elements. The average concentrations of Na, K, Ca, Cu and Fe were respectively found within the ranges of 6.12–6.14, 0.67-8.68, 4.84-45.30, 0.00-0.008 and 0.06-0.014 mgg^{-1}. The values of the element expressed per serving dishes of the samples were appreciable relative to recommended daily intakes. This implies that the foods can be relevant in the management of Mineral Deficiency Diseases (MDD). Fe and Cu were below the toxic limit and lead was not detectable. The foods were found to be generally safe for consumption. Correlation analysis showed that Na and Ca or K as well as Fe and Cu have high correlation. These elements therefore constitute the unique element signature of the local soups in Minna. The Hierarchical Cluster Analysis of the mineral content data revealed two close substitute food pairs: *Miyan yakuwa* and *Danyen kubewa* as well as *Miyan ku*ka and *Miyan karkashi*. The result implies that in cases of unavailability or scarcity of one of the pairs, the other paired food can be consumed. The paired foods have equivalent mineral content. The Principal Component Analysis loading-score biplot indicated that Miyan yakuwa, Danyen kubewa. Miyan agushi and Miyan taushe are calcium, sodium, and potassium rich soups. The result also reveals that Jan miya is relatively rich in copper and iron..*Miyan kuka* and *Miyan Karkashi* particularly have lower concentration of elements.

Key words: Minerals, local soups, Minna, chemometrics, Mineral Deficiency Diseases

1.0 INTRODUCTION

Food is any edible substance, which could be plant or animal that contains nutritive components which when ingested and digested can sustain life, provide growth and maintain the health of the body generally [1 - 4].Soups are foods in form of liquid. It could be served cold or hot depending on the types. Most foods contain ingredients such as meat, fish, vegetables with appropriate salt and sauces to taste [5 -8]. Soups like food are essential for growth and development of strong muscles, teeth and bones and repair of worn out tissues, it keeps the body warm and provides energy, and helps in fighting diseases. Food also helps the brain to grow and function properly.

Mineral content of foods are essential. They have been found to be helpful in relieving insomnia [9]. They also help in improving dental health [10, 11] act as supporters in boosting the immune system [12] and prevent muscle cramps and prevent muscle sickness such as Nutritional Muscular Dystrophy; which is a disease caused by deficiency of Selenium and Vitamin E in dietary intake [13], some minerals reduce tension in the blood vessels and ensure proper distribution of oxygen to the vital organs in the body.

The Nigerian soups usually have a popular recipe, and their recipes consist of the major ingredients (usually comprising vegetables such as spinach, jute, or plant seeds like Melon seed, or a combination of both) and additives. The soups are versatile and can be prepared in different ways involving addition of variety of additives such as different types of meat, fish, seafood (Crayfish, Periwinkle), etc. Some Nigerians prefer to use Bouillon (Maggi) cubes as seasoning, while others prefer the more natural seasoning known as Dawadawa (Locust bean seed). Other spices like pepper, ginger, garlic, etc., are added to the soups also, depending on the taste of the person doing the cooking.

Minna is a town in North central Nigeria and capital city of Niger State. The Northern region of Nigeria has numerous soups and foods which serve as attractions for tourists all over the world. These tasty traditional soup and food of the north have accorded the region a peculiar national food identity. Several researchers who have worked on local soups [14, 15].

Rapid urbanization and economic development have resulted in drastic changes in diets, with developing preference towards refined food and nutritionally deprived junk food. Similarly, a lot of problems caused by company processed foods like metal leachate, interference have made it compelling to study local soups and foods. This study is aimed at extracting optimum information on the mineral content of local soups in Minna using spectroscopic data and chemometrics pattern recognition techniques.

2.0 MATERIALS AND METHODS

2.1 Collectionand Treatment of Samples

Each of seven locally prepared soup samples were purchased from three separate sources (triplicates) within Minna, Niger State from local food vendors and local restaurants. This pattern of purchase was used in order to preserve their local identities and traditional values. Information about the various soup samples and their major ingredients were obtained from the food vendors and some experienced restaurants operatives for standard purpose. Table 1 shows the soup description and their ingredients. The sampled soups are the adult - size dishes, cooked and served by the food vendors and restaurants. The samples were collected in leak-proof polythene bags. The samples were sun dried and later blended. The seven homogenized samples were transferred into separate Pyrex^{TM} beakers covered with perforated aluminum foils in order to allow easy escape of steam and simultaneously avoid aerial cross - contamination of the soup samples during drying. Each sample was labeled and then transferred into an oven with temperature between 100 - 110^{o}C for approximately 48 hours. After drying, the weight recorded foreach sample. The samples were kept for subsequent analysis.

2.2 Digestion of samples

Wet ashing procedure was used, the procedure enlisted the use of concentrated nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) as the major reagents. 1g of each of the homogenised dry soup samples was accurately weighed into 100 cm^3 beakers. 14cm^3 of nitric acid was added to soak the samples, the beakers were covered with aluminium foils and kept in a fume cupboard for 6 hours. High Purity Concentrated HNO_3 acid (65%) and hydrogen peroxide (40%) reagents and deionized water were used. with application of heat for digestion. The adopted digestion procedure is described in [3].The freshly digested samples appeared as lightly coloured solutions, the solutions were then filtered to remove possible particles using white filter papers and then transferred into standard 100 cm^3 volumetric flasks and made up to mark using deionized water. The filtered samples appeared as light yellow or clear solutions.

2.3 Instrumental Determination of the Elements

Analysis on the trace minerals Cu, Fe, and Pb,in triplicates, was carried out using Atomic Absorption Spectrophotometry while Flame Emission Spectroscopy was used for triplicate determination of essential minerals Na, Ca and K for all soup samples, in both cases, the analysis was carried out following the manufacturer's recommendations.Bulk Scientific Atomic Absorption Spectrophotometer; Model: Accusys 211 (Manufacturer: USA) was used.

2.4 Data acquisition, chemometrics preprocessing and quality assurance

Descriptive statistics and the multivariate correlation analysis were carried out on Microsoft Excel spreadsheet for Windows. The PCA and HCA were performed using MATLAB with PLS toolbox.

Accuracy of the results obtained was validated with the use of SRM 1570a: a certified reference material of trace elements in spinach leaves. Only the good-fit calibration plots with r^2around 0.950 were adopted.

3.0 RESULTS AND DISCUSSION

3.1 Mineral Content of the Local Soups

The studied soups have appreciable presence of the essential elements in general. Optimum levels of Na, K, Ca, Cu and Fe are respectively found in *Miyan yakuwa, Dhayen kubewa, Miyan yakuwa, Jan-Miyan and Jan-Miyan samples.* Table 2 shows the concentration of the elements in mg per g concentration unit. However, the concentration expressed per served dish gives more real concentration consumed by the public. The highest amount of Na, K, Ca, Cu and Fe are respectively obtained in dishes of *Miyan agushi, Miyan agushi, Miyan yakuwa, Jan-miyan and Jan miyan*. These optimal values of Na, K, Ca, Cu and Fe are respectively 110.7, 15.0, 129.4, 111.1 and 136.3%relative to lower values of the daily Recommended Dietary Allowances [16]. This implies that studied soup samples are capable of supplying the daily needed essential elements. This study however revealed that there is still potassium deficit that could not be met by the intake of the selected soups. There is high Na value in all soups. This can be attributed to inclusion of table salts while preparing all soups.

3.2 Chemometrics Study

3.2.1 Correlation Analysis

The relevance of the correlation matrix analysis is to give insight into element interdependence in the studied soups[17, 18]. Information about the interdependence of the physico-chemical properties is needed to know if increasing consumption of the soups for certain desirable mineral elements might carry along the correlated undesirable property. Similarly, the correlation analysis information also helps in characterization of the general profile of the soups [2, 3, 4 17, 18].Table 4gives the correlation matrix of the element content of selected local soups.Strong correlations are observed amongNa and Ca or K as well as between Fe and Cu. In food quality control study, these elements represent the signature of the local soups. The high correlation values between these elements imply that they are consistently interdependent on one another in the selected soups.

3.2.2 Hierarchical Cluster Analysis

The HCA technically interprets the inter-point distances between the each of the soup samples and plots a two-dimensional Dendrogram. Cluster analysis is able to classify close substitute soups in terms of similarity of mineral element content.The Dendrogram depicted in Figure 1showed that the pairs of *Miyan yakuwa* and *Danyen kubewa* are close substitute soups. The other close soup pairis *Miyan kuka and Miyan karkashi.* This observation implies that in cases of unavailability or scarcity of one of the pairs, the consumption of the other pair can be made because the soup in each pair has equivalent mineral content [19, 20]. The HCA reveals two groupings of the soups. The larger group includes soups labelled 2, 4, 5, 6 and 7. Soups labelled 1 and 3 constitute the second group.

3.2.3 Principal Component Analysis

The plots obtainable from PCA include Eigen value, loading, score, residual and biplot. The biplot appeared to be most informative as the smaller matrices' size of the data may under report the latent information. The biplot shown in Figure 2is advantageous in that it illustrates the correlation of soup samples with mineral elements variable on common principal component planes [19, 20]. This plot characterizes the soups into two major groups just like as previously shown in HCA Dendrogram in Figure 1. In this case, biplot clearly indicated the correlated elements. Thus we have two large groups with three sub-groupings. The sub-group I consists of soups: *Miyan yakuwa, Danyen kubewa. Miyan agushi and Miyan taushe* respectively labelled 4, 5, 6

and 7. They are Na, K and Na rich foods. The sub-group II consists of only Jan miyan soup labelled as 2. It is unique for being a Cu and Fe containing soup. The sub-group III consists of soups: *Miyan kuka and Miyan karkashi* respectively labelled 1 and 3. This is a sub-group of soups with a particularly too low concentrations of the essential minerals. This result from biplot shows the relevant soups which can be useful in the management of mineral deficiency diseases.

Table 1 : Ingredients and Description of Selected Soup Samples

Soup	Description	Ingredients
1. MiyanKuka	The soup is made from powdered baobab leaves. It has a greenish brown colouration.	Dry Baobab leaves powder, Palm oil, Locust beans, Chilli pepper, Onion, Maggi cubes, Salt.
2. Jan - Miya	It is a bright red coloured soup prepared using red pepper and red tomatoes.	Chilli Pepper, Onion, Maggi cubes, Salt.
3. Miyan Karkashi	This soup is prepared using Karkashi, it is known for its Blackish appearance and for being highly slippery when cooked.	Karkashi, Potash, Grounded Fresh Pepper, Locust beans, Chilli pepper, Onion, Maggi cubes, Salt.
4. Miyan Yakuwa	The main ingredient of this soup is the Yakuwa leaves, it has a reddish colour with green sprinkles when cooked.	Yakuwa leaves, Raw groundnut paste, Fresh Tomato, Red pepper, Maggi cubes, Salt, Locust beans, Onion, Yaji, Vegetable oil.
5. Miyan Agushi	This soup contains the grounded seeds of melon, spinach or other vegetables. It has a yellow colouration with sprinkles of green when cooked.	Agushi (Melon seed), Spinach (or other vegetables e.g. bitter - leaf), Maggi cubes, Salt, Locust beans, Onion, palm oil, Salt, Pepper.
6. MiyanTaushe	It is prepared with mashed pumpkin pulp, it is an orange coloured, thick soup.	Pumpkin leaf, Yakuwa leaves (sorrel), Spinach, raw Groundnut (or groundnut paste), Locust beans, Chilli pepper, Palm oil, Red bell pepper, Tomatoes, Onion, Maggi cubes, Salt.
7. DayenKubewa	It is prepared using the edible green seed pods of okra. It is greenish in colour and has a slimy, slippery feel when cooked.	Diced fresh Okra, Salt, Maggi cubes, dried or fresh pepper, palm oil.

Table 2 : Mineral Content of soup samples (mgg^{-1})

	Soups	Na	K	Ca	Cu	Fe	Pb
1	*Miyan Kuka*	9.07±0.02.	0.67±0.00	4.84±0.01	ND	0.1177±0.02	ND
2	*Jan - Miyan*	10.1±0.03	2.44±0.02	5.88±0.02	0.0075±0.00	0.135±0.02	ND
3	*Miyan Karkashi*	6.12±0.02	0.96±0.01	6.65±0.02	ND	0.0648±0.00	ND
4	*Miyan Yakuwa*	40.2±0.10	5.9±0.02	34.4±0.11	ND	0.122±0.01	ND
5	*Miyan Agushi*	17.1±0.07	4.22±0.01	8.92±0.02	0.0043±0.00	0.1025±0.02	ND
6	*Miyan Taushe*	18.3±0.05	3.55±0.01	13.1±0.02	0.0048±0.00	0.0738±0.00	ND
7	*Dayen Kubewa*	61.4±0.09	8.68±0.03	45.3±0.20	ND	0.1218±0.01	ND

ND : Not Detected, Average of triplicates ± standard deviations

Table 3 : Mineral Content of soup samples in average dish size (mg per size*)

	Soups	Na	K	Ca	Cu	Fe	Pb
1	*Miyan Kuka*	293.9±0.23	21.7±0.93	156.8±2.33	ND	3.8±0.05	293.9±0.23
2	*Jan - Miyan*	814.1±3.47	193.4±3.12	473.9±2.85	0.6±0.01	10.9±0.11	814.1±3.47
3	*Miyan Karkashi*	414.3±5.63	65.0±2.11	450.2±3.02	ND	4.4±0.09	414.3±5.63
4	*Miyan Yakuwa*	1210.0±7.0	177.6±3.46	1035.4±6.23	ND	3.7±0.02	1210.0±7.03
5	*Miyan Agushi*	1328.7±5.1	327.9±1.11	693.1±3.99	0.3±0.02	8.0±0.11	1328.7±5.19
6	*Miyan Taushe*	1118.1±6.6	216.9±1.79	800.4±4.11	0.3±0.00	4.5±0.07	1118.1±6.66
7	*Dayen Kubewa*	1131.0±7.4	159.9±2.02	834.4±5.52	ND	2.2±0.02	1131.0±7.43
	Average Content	901.4±4.72	I66.1±1.98	634.9±2.54	0.4±0.01	5.4±0.14	901.4±4.72
	**RDA (Upper	1500	4700	1000	1	30	1500
	**RDA (Lower	1200	1825	800	0.54	8	1200

ND : Not Detected, *: Varied serving size in g, RDA: Required Dietary Allowance ** : US Department of Health and Human Service (2005), Average of triplicates ± standard deviations

Table 4: Correlation Matrix of the mineral Content of Soups

	Na	K	Ca	Fe	Cu
Na	1.00				
K	0.88	1.00			
Ca	0.87	0.59	1.00		
Fe	0.09	0.47	-0.24	1.00	
Cu	0.26	0.59	-0.07	0.92	1.00

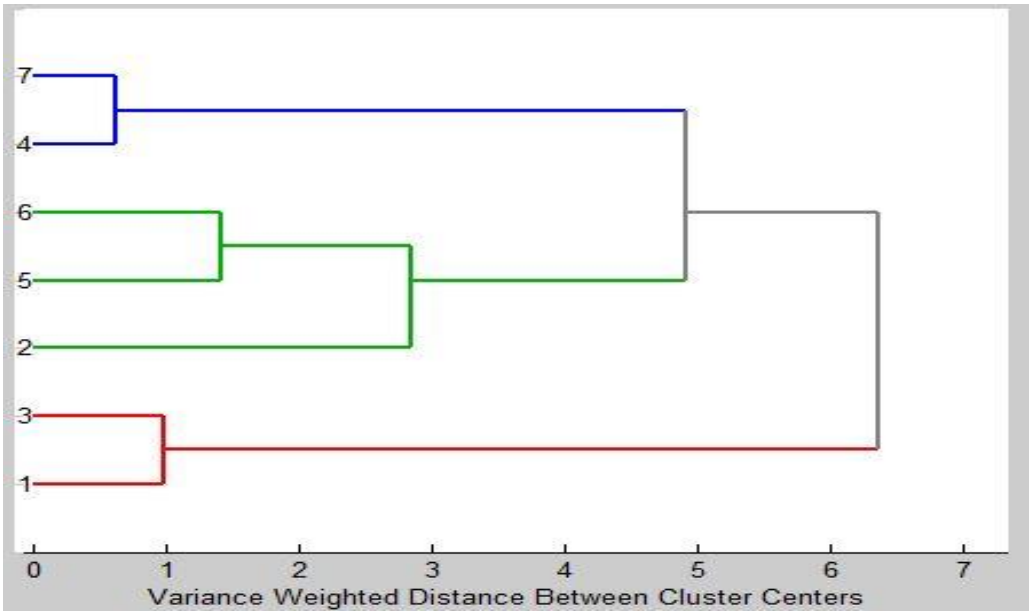

Figure 1: Dendrogram of HCA of Mineral content of Soup

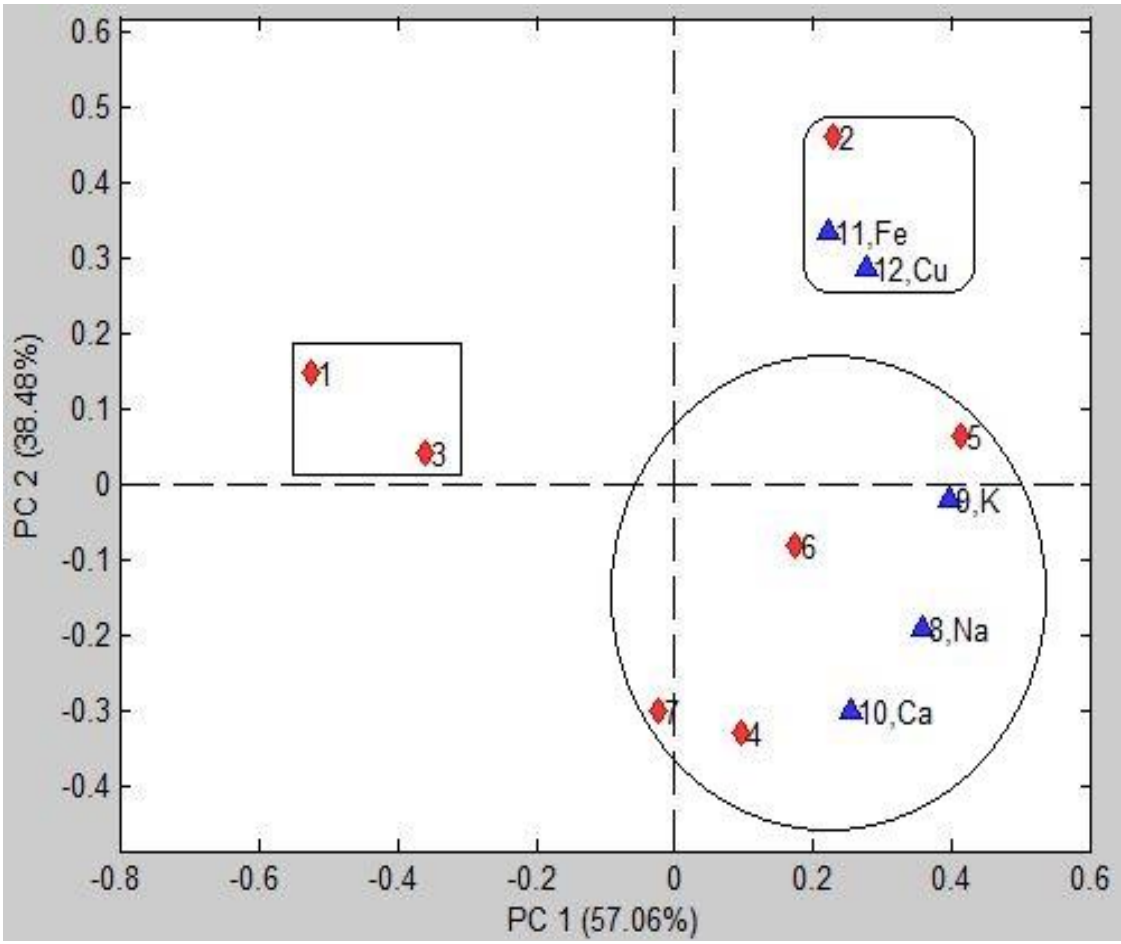

Figure 2: PCA Biplot (Loading/Score) of samples dataset

4.0 CONCLUSION

The element content expressed per serving dishes were appreciable relative to recommended daily intakes. This implies that the soups can be relevant in the management of Mineral Deficiency Diseases (MDD). Fe and Cu were found within acceptable essential elements limit. Both are below the toxic limit. Similarly, lead was not detected. The soups are therefore safe for consumption. *Dahyen kubewa* and *Miyan yakuwa* have prominent content of studied elements with relative higher values making them good source of essential mineral elements.

Correlation analysis showed that Na and Ca/K as well as Fe and Cu are well correlated and hence have good interdependence. These elements characterize the unique element signature of the local soups in Minna. The Hierarchical Cluster Analysis of the mineral content data identified two very close soup pairs in terms of the mineral contents. The pairs are *Miyan yakuwa* and *Danyen kubewa* as well as *Miyan kuka* and *Miyan karkashi*. The biplot of loading and score of the Principal Component Analysis indicated that *Miyan yakuwa, Danyen kubewa. Miyan* agushi and *Miyan taushe* are calcium, sodium and potassium rich soups while *Jan miya* is relatively rich in copper and iron

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