Türk Biyokimya Dergisi [Turkish Journal of Biochemistry–Turk J Biochem] 2014; 39 (1) ; 45–50
doi: 10.5505/tjb.2014.61587

Research Article [Araştırma Makalesi]

Yayın tarihi 30 Mart, 2014 © TurkJBiochem.com

[Published online 30 March, 2014]

# Possible correlation between mineral profile and protein content of foods

## [Besinlerde mineral profili ve protein oranlarının muhtemel ilişkisi]*

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Registered: 5 July 2012; Accepted: 6 July 2013

[Kayıt Tarihi: 5 Temmuz 2012; Kabul Tarihi: 6 Temmuz 2013]

**ABSTRACT**

**Objective:** High K+ value does not serve just to maintain osmotic balance. It is hypothesized that the relatively high intracellular levels of K+ maintained by most cells functions to furnish other cellular functions such as augmentation of protein levels through either synthesis or metabolism of protein. The study aimed at establishing a correlation between the mineral and protein contents of foods.

**Methods:** The mineral (Na+, K+, Ca2+ and Mg2+) and protein contents of some randomly selected plant liquid products were estimated. Concentration-dependent mineral profiles were drawn up and ratios of the various minerals, protein/ [K+], protein/[Na+] and [K+]/ [Na+] versus protein levels were calculated.

**Results:** Their mineral profiles were palm oil: [Ca2+] > [Na+] > [Mg2+] > [K+]; palm kernel oil: [Ca2+] > [Na+] > [K+] > [Mg2+]; Raphia hookeri wine: [Ca2+] > [Na+] > [Mg2+] > [K+] and Terminalia catappa decoction: [Ca2+] > [Na+] > [K+] > [Mg2+] relative to [K+] > [Na+] > [Mg2+] > [Ca2+] in normal animal or high protein tissues. Their protein contents (g/ 100 ml) were 2.71±0.05, 0.91±1.27, 2.77±0.04 and 5.30±0.09, respectively. The results clearly showed distinctive mineral and protein profiles that may correlate, especially in relation to [K+]/ [Na+] ratio; protein content increasing with increase in the ratio. Various enzyme systems involved in mineral and protein metabolism are likely to be affected under their varying concentrations.

**Conclusion:** Protein content seemed facilitated by high [K+]/ [Na+] ratio.

**Key Words:** Correlation, foods, mineral profile, plant tissue, protein contents.

**Conflict of Interests:** The authors do not have any conflict of interests.

**ÖZET**

**Amaç:** Yüksek $K^+$ değerleri sadece ozmatik dengeyi sağlamakla kalmaz. Yüksek $K^+$ değerlerinin protein seviyesinde yapım ve yıkım hızlarının ayarlanması sayesinde denge sağladığı gibi diğer hücresel olaylarda rol oynadığı hipotez edilmektedir. Bu çalışma mineral ve protein çeşitliliği arasındaki ilişkiyi tespit etmei amaçlamaktadır.

**Yöntemler:** Rastgele seçilmiş bazı sıvı bitki ürünlerindeki ($Na^+$, $K^+$, $Ca^{2+}$ ve $Mg^{2+}$) mineralleri ve protein ceçitleri belirlenmiştir. Konsantrasyona dayalı mineral profilleri çizilmiş ve çeşitli mineral protein (protein/ [$K^+$], protein/[$Na^+$] ve [$K^+$]/ [$Na^+$] ile protein) oranları hesaplanmıştır.

**Bulgular:** Mineral profilleri normal hayvan ya da yüksek proteinli dokulardaki [K+] > [Na+] > [$Mg^{2+}$] > [$Ca^{2+}$] ile karşılaştırıldığında şöyle bulunmuştur: palmiye yağı [$Ca^{2+}$] > [$Na^+$] > [Mg2+] > [$K^+$]; palmiye kabuk yağı [$Ca^{2+}$] > [$Na^+$] > [$K^+$] > [$Mg^{2+}$]; Raphia hookeri şarabı [$Ca^{2+}$] > [$Na^+$] > [$Mg^{2+}$] > [$K^+$]; Terminalia catappa özü [$Ca^{2+}$] > [$Na^+$] > [$K^+$] > [$Mg^{2+}$]. Protein değerleri (g/ 100 ml) sırası ile 2.71±0.05, 0.91±1.27, 2.77±0.04 ve 5.30±0.09 dir. Sonuçlar açıkca mineral ve protein değerleri arasında belirgin bir ilişki olduğunu özellikle [$K^+$]/ [$Na^+$] oranındaki artış ile protein değerlerindeki artışın alakalı olduğunu göstermektedir. Protein ve mineral yıkımında rol oynayan bazı enzim sistemlerinin bu değerlerdeki değişimden etkilenmesi olasıdır.

**Sonuç:** Protein değerlerinin yüksek [$K^+$]/ [$Na^+$] oranından etkilendiği düşünülmektedir.

**Anahtar Kelimeler:** İlinti, besinler, mineral profile, bitki dokusu, protein değerleri

**Çıkar Çatışması:** Yazarların çıkar çatışması yoktur.

## Introduction

A tissue is a group of cells, often similar in structure and origin, operating together to perform a specialised function [1]. Each organelle or cellular compartment has an aqueous fluid or matrix that contains various ions, small molecules, and a variety of proteins, and in some cases nucleic acids. Each has a distinctive pH and ionic composition. The major extracellular cation is $Na^+$, with a concentration of ~140 meq $L^{-1}$ (mM); very little $Na^+$ is present in intracellular fluid. The major intracellular cation is $K^+$. $Mg^{2+}$ is present in both extra- and intracellular compartments at concentrations much lower than those of $Na^+$ and $K^+$ [2, 3]. Reports on mineral composition of carcass composite meat from goat, chicken and beef have presented trends consistent with intracellular high potassium cation concentrations; with concomitant high levels of protein [4-7]. Potassium is also the most abundant cation in plants and plays an important role in processes such as cell elongation, leaf movements, tropisms, metabolic homeostasis, germination, osmoregulation, stomatal movements, and sodium stress [8]. When the concentrations of the interstitial, intracellular and plasma electrolytes as reported by [2] are summed up, the order $[Na^+] > [K^+] > [Mg^{2+}] > [Ca^{2+}]$ is presented. However, when only the concentrations of the intracellular and interstitial electrolytes are summed up, the order becomes $[K^+] > [Na^+] > [Mg^{2+}] > [Ca^{2+}]$. A profile of $[Na^+] > [K^+] > [Ca^{2+}] > [Mg^{2+}]$ was reported for human plasma with protein contents of between 5.5 to 8.0 g/dl [3].

Proximate analyses of most food materials of plant origin present low protein contents; with almost the same mineral profile as animal tissues [9]. $K^+$ has been reported to be important for intracellular protein synthesis as it is required for translation. Inhibition of the $Na^+/K^+$-ATPase blocks protein synthesis. Potassium ion is required for the maintenance of ribosomal structure, tRNA binding to ribosomes; with protein synthesis being completely blocked below 50 mM [10, 11].

Palm oil (PO) is extracted from the fleshy mesocarp of the fruits of tropical palm tree (*Elaeis guineensis*) while palm kernel oil (PKO) is extracted from the kernel of the palm fruit [12]. Leaves and bark of the different species of Tropical almond (*Terminalia* species) have a wide range of ethno-medicinal uses [13]. Exudates from *Raphia hookeri* are tapped and fermented into wine [14].

The compositions of foods are generally believed to be genetically determined. However, factors other than the genes may also influence such compositions. Reports on these other factors are scanty. Protein is a nutrient. Its level in food may be influenced by the spectra of minerals affecting its synthesis or level. The study evaluated the protein and mineral contents of some randomly selected plant fluid products like PO, PKO, *Raphia hookeri* wine and decoction of *Terminalia catappa* and used such information to suggest correlations between their mineral profiles and protein contents.

## Materials and Methods

### *Procurement of samples*

Fresh PO sample was purchased from Nkwo-Ukwu Market, Ihiagwa, Nigeria. The PKO used in the study was purchased from Camela Vegetable Oil Limited, Irete – Owerri, Nigeria. The palm wine used was tapped from *Raphia hookeri* G. Mann. and H. Wendl. trees by palm wine tappers at Orodo, Mbaitoli Local Government Area of Imo State, Nigeria. The palm wine was simply the exudates of the palm trees tapped into vessels by native experts who do not add any yeast to it. Fallen dry leaves of *Terminalia catappa* Linn. (Herbarium number: IMSUH 126) were picked from under their trees at Nekede, Owerri, Nigeria. The voucher leaf sample was deposited in the herbarium of the Department of Plant Science and Biotechnology, Imo State University, Owerri, Nigeria. Our experimental samples were randomly selected.

All the chemicals used were of analytical-reagent grade and were purchased locally.

### *Preparation of decoction*

The fallen dried leaves of *T. catappa* Linn. were cleaned of debris and washed in deionised water. They were then mopped dry of water, chopped into bits and re-dried in an oven at 60°C for 10 h. Leaf bits (100 g) were put into an aluminum pot and 4600 ml of deionised water was added. This was brought to boil and allowed to simmer for 20 min. The decoction produced was filtered off the leaf bits using muslin cloth.

### *Analyses of samples*

The protein contents of the samples were determined using the methods of [15]. Briefly, 2.0 ml of the respective sample was introduced into a 200.0 ml Kjeldahl flask. Digestion catalyst (3.0 g; prepared by mixing 10.0 g of anhydrous $Na_2SO_4$ and 1.0 g $CuSO_4$), 20 ml of concentrated $H_2SO_4$ and 4.0 g of anti-bumping chips were poured in. The mixture was digested in a fume cupboard (for 4 h) until the dirty brown coloured solution turned clear green and the digest diluted to 100.0 ml with distilled water. An aliquot (10.0 ml) of the diluted digest was transferred into a micro-Kjeldahl distillation apparatus and 30.0 ml of 40 % NaOH introduced into the distillation flask. The mixture was distilled into 10.0 ml of 2 % boric acid solution that contained 2 drops of methyl red – methylene blue double indicators. The distillate was titrated to the end point with 0.1 M HCl and the protein content calculated.

Analyses for some of their mineral contents (mg/ 100 ml) were determined using the methods of [15-16]. Briefly, 50.0 ml of the respective sample was evaporated at 95°C for 30 min to a semi-solid consistency using a hot plate.

The semi-solid sample was then digested by mixed-acid digestion using 10 ml of conc. $HNO_3$ and 5.0 ml of 62% $HClO_4$ until the appearance of white fumes. The digest was allowed to cool, and then made up to 100.0 ml with deionized water. Aliquots of the respective diluted digest were then aspirated in an atomic absorption spectrophotometer (Perkin-Elmer model 403) for the determination of a mineral's content using the appropriate hallow cathode lamp and at the appropriate wavelength.

### *Statistical analysis*

Data were analysed using the analysis of variance (ANOVA) as described by [17]. Values were declared significant at $p \leq 0.05$.

## Results and Discussion

Our samples were randomly selected and represented three main fluid products of plant origin. However, values of parameters of animal tissues, animal fluid (like cow milk) and plant solid products were enlisted from literature and presented in our tables to ensure broad comparisons and deductions.

The *R. hookeri* wine contained the highest amounts of $K^+$, $Na^+$, $Mg^{2+}$ and $Ca^{2+}$ (Table 1). The most abundant mineral in our samples was calcium (Tables 1 and 2). The mineral profiles of the samples contrasted sharply with those reported for animal tissues [5-6], soybean and cowpea [9] as presented in Table 1 with potassium being their most abundant mineral. The samples presented high levels of calcium ions in the cells from which the oils, wine and decoction were produced. The mineral profiles of the animal tissues (presented in Table 2) reflect that which is found in human cells [3]. Mammalian extracellular mineral profile is $[Na^+] > [K^+] \geq [Ca^{2+}] > [Mg^{2+}]$ as reported by [3] and [18]. Intracellular $Na^+$, $K^+$ and $Ca^{2+}$ concentrations depend mostly on the activity of $Na^+/ K^+$-ATPase [3-4], [18-20]. The ATPase activity is in turn dependent on the concentrations of $Mg^{2+}$ and ATP and can also be inhibited by cardiac glycosides [3]. Reduction or inhibition of $Na^+/ K^+$-ATPase activity was reported to increase intracellular concentrations of $Ca^{2+}$ and $Na^+$ [21] and reduce intracellular concentration of $K^+$ [11]. This also leads to a reduction in $[K^+]/ [Na^+]$, $[K^+]/ [Ca^{2+}]$ and $[Mg^{2+}]/ [Ca^{2+}]$ ratios. The $[K^+]/ [Na^+]$, $[K^+]/ [Mg^{2+}]$, $[K^+]/ [Ca^{2+}]$ and $[Mg^{2+}]/ [Ca^{2+}]$ ratios of our samples were reduced relative to those of the animal tissues and legumes (Table 3); suggestive of perturbed $Na^+/ K^+$-ATPase activity. High level of $Ca^{2+}$ was also reported in oil palm wine [22]; the level being higher than those of $K^+$ and $Na^+$, hence presenting the mineral profile as $[Ca^{2+}] > [K^+] > [Na^+]$. The $[K^+]/ [Ca^{2+}]$ and $[Na^+]/ [Ca^{2+}]$ ratios were also reduced in the oil palm wine examined by [22]; its $[K^+]/ [Na^+]$ ratio however compared favorably with that found in normal human cells (as presented in Table 3). Our reference to the human intracellular milieu in Tables 2 and 3 is not unique as it highlights the possible conserved evolutionary significance of the subject and our observations while still allowing diversity. Recall that unity in diversity is a central biological principle which underlies conserved biochemical systems. The fundamental properties of all cells have been reportedly conserved during evolution [18].

Our samples had reduced concentrations of $K^+$ (Tables 1 and 2) and low protein contents relative to the animal tissues and legumes (Table 4). The oil palm wine examined by [22] also had a low protein value of 1.31% (or 1.31 g/100 ml). The low protein contents of our samples may be as a result of reduced cellular $[K^+]$ which is required for protein synthesis in cells. The $[K^+]/ [Mg^{2+}]$ ratio for PKO was within the normal value in cells (Table 3); for instance being greater than unity. This might have been as a result of the absence or low chlorophyll content of palm kernels. Recall that kernels are the progenitors of leaves and that $Mg^{2+}$ is the central ion in chlorophyll. The $[K^+]/ [Mg^{2+}]$ ratio of the decoction was also within

**Table 1.** Mineral contents (mg/ 100 ml) of samples relative to animal tissues, cow milk and legumes

| | Minerals* | | | |
|---|---|---|---|---|
| Sample | $K^+$ | $Na^+$ | $Mg^{2+}$ | $Ca^{2+}$ |
| Palm oil | $0.72 \pm 0.01^d$ | $1.15 \pm 0.01^c$ | $0.80 \pm 0.00^b$ | $3.70 \pm 0.02^b$ |
| Palm kernel oil | $0.76 \pm 0.01^c$ | $1.23 \pm 0.01^b$ | $0.68 \pm 0.01^c$ | $2.74 \pm 0.00^c$ |
| *T. catappa* decoction | $0.82 \pm 0.02^b$ | $0.95 \pm 0.01^d$ | $0.64 \pm 0.01^d$ | $1.38 \pm 0.01^d$ |
| *Raphia hookeri* wine | $0.90 \pm 0.02^a$ | $1.30 \pm 0.02^a$ | $0.96 \pm 0.01^a$ | $5.06 \pm 0.00^a$ |
| Goat tissue [5] | 308.3 | 77.1 | 23.7 | 25.3 |
| Beef [6] | 363 | 51 | 25 | 4.5 |
| Cow milk[23] | 1.30 | 51.92 | 1.03 | 4.03 |
| Soybean [9] | 1797 | 2 | 280 | 277 |
| Cowpea [24] | 278 | 4 | 53 | 24 |

*Values are mean ± SD of triplicate determinations. Values on the same column bearing the same superscript letter of a, b, c or d are not significantly different ($p>0.05$).

**Table 2.** Mineral profile of human cell, samples, animal tissues, cow milk and legumes*

| Sample | Mineral profile |
|---|---|
| $Normal_{Human\ cell\ (intracellular)}$ [3]-[4], [18]-[20] | $[K^+] > [Na^+] > [Mg^{2+}] > [Ca^{2+}]$ |
| Palm oil | $[Ca^{2+}] > [Na^+] > [Mg^{2+}] > [K^+]$ |
| Palm kernel oil | $[Ca^{2+}] > [Na^+] > [K^+] > [Mg^{2+}]$ |
| *T. catappa* decoction | $[Ca^{2+}] > [Na^+] > [K^+] > [Mg^{2+}]$ |
| *Raphia hookeri* wine | $[Ca^{2+}] > [Na^+] > [Mg^{2+}] > [K^+]$ |
| Goat tissue | $[K^+] > [Na^+] > [Mg^{2+}] > [Ca^{2+}]$ |
| Beef | $[K^+] > [Na^+] > [Ca^{2+}] > [Mg^{2+}]$ |
| Cow milk | $[Na^+] > [Ca^{2+}] > [K^+] > [Mg^{2+}]$ |
| Soybean | $[K^+] > [Mg^{2+}] > [Ca^{2+}] > [Na^+]$ |
| Cowpea | $[K^+] > [Mg^{2+}] > [Ca^{2+}] > [Na^+]$ |

*Based on Table 1.

**Table 3.** Ratios of concentration of minerals relative to animal tissues, cow milk and legumes

| Samples | Ratio of minerals* | | | | | |
|---|---|---|---|---|---|---|
| | $[K^+]:[Na^+]$ | $[K^+]:[Mg^{2+}]$ | $[K^+]:[Ca^{2+}]$ | $[Mg^{2+}]:[Ca^{2+}]$ | $[Na^+]:[Mg^{2+}]$ | $[Na^+]:[Ca^{2+}]$ |
| $Normal_{Human\ cell\ (intracellular)}$ | 14.00‡ | 291.67‡ | 1400000.00‡ | 4800.00‡ | 20.83‡ | 100000.00‡ |
| Palm oil | 0.63 | 0.9 | 0.19 | 0.22 | 1.44 | 0.31 |
| Palm kernel oil | 0.62 | 1.12 | 0.28 | 0.25 | 1.81 | 0.45 |
| *T. catappa* decoction | 0.86 | 1.28 | 0.59 | 0.46 | 1.48 | 0.69 |
| *R. hookeri* wine | 0.69 | 0.94 | 0.18 | 0.19 | 1.35 | 0.26 |
| Goat tissue | 4.00 | 13.01 | 12.19 | 0.94 | 3.25 | 3.05 |
| Beef | 7.12 | 14.52 | 80.67 | 5.56 | 2.04 | 11.33 |
| Cow milk | 0.03 | 1.26 | 0.32 | 0.26 | 50.41 | 12.88 |
| Soybean | 898.2 | 6.42 | 6.49 | 1.01 | 0.007 | 0.007 |
| Cowpea | 69.5 | 5.23 | 11.58 | 2.21 | 0.075 | 0.17 |

*Based on Table 1.
‡[3]-[4], [18]-[20].

**Table 4.** Protein contents relative to animal tissues, cow milk and legumes.

| Sample | Protein content (g/ 100 ml)* |
|---|---|
| Palm oil | $2.71 \pm 0.02^c$ |
| Palm kernel oil | $0.91 \pm 0.02^d$ |
| *T. catappa* decoction | $5.30 \pm 0.09^b$ |
| *Raphia hookeri* wine | $2.77 \pm 0.04^c$ |
| Goat tissue [5] | 22.00 |
| Beef [6] | 22.00 |
| Cow milk [23] | 3.20 |
| Soybean [9] | 36.49 |
| Cowpea [24] | 7.73 |

*Results are mean ± SD of triplicate determinations.
Values on the same column bearing the same superscript letter of a, b, c or d are not significantly different ($p>0.05$)

**Table 5.** Protein to $[K^+]$ and protein to $[Na^+]$ ratios*

| Sample | Protein/[$K^+$] ratio | Protein/[$Na^+$] ratio |
|---|---|---|
| Palm oil | 3763.88 | 2356.52 |
| Palm kernel oil | 1197.36 | 739.84 |
| *T. catappa* decoction | 6463.41 | 5578.95 |
| *Raphia hookeri* wine | 3077.78 | 2130.77 |
| Goat tissue | 71.36 | 285.34 |
| Beef | 60.61 | 431.37 |
| Cow milk | 24615.4 | 616.33 |
| Soybean | 20.36 | 18245.00 |
| Cowpea | 27.81 | 1932.50 |

*Based on Tables 1 and 4.

the normal value for cells because [$Mg^{2+}$] is low in leaves undergoing senescence and/ or abscission. It is usually noticed that leaves first turn yellow because of reduced [$Mg^{2+}$] occasioned by loss and/ or translocation of $Mg^{2+}$, then brown before abscission. The more important ratios seemed to have been those of [$K^+$]/[$Na^+$], [$K^+$]/[$Ca^{2+}$] and [$Mg^{2+}$]/[$Ca^{2+}$]; with the [$K^+$]/[$Na^+$] ratio being the most important (Table 3) because soybean had lower [$K^+$]/[$Ca^{2+}$] and [$Mg^{2+}$]/[$Ca^{2+}$] ratios than the animal tissues and cowpea presented, yet had the highest protein content; with over an 890 fold increase in the [$K^+$]/[$Na^+$] ratio. Increase in [$K^+$]/ [$Na^+$] ratio, which is a result of increase in intracellular [$K^+$] and decrease in [$Na^+$], seemed to have engendered protein synthesis and/ or stabilization. While this assertion supports reports that $K^+$ is required for protein synthesis, it also suggests that $Na^+$ may suppress it and may antagonize $K^+$ activity. It may further explain why protein synthesis occurs intracellularly (where [$K^+$] > [$Na^+$]) and not extracellularly (where [$K^+$] < [$Na^+$]). The *T. catappa* decoction had the highest ($p < 0.05$) protein content among our samples while the PKO had the lowest ($p < 0.05$) protein content (Table 4). But the high protein tissues from animals, cowpea and soybean had considerably very low protein to [$K^+$] ratio (Table 5). In particular, soybean with the highest protein content had the lowest protein to [$K^+$] ratio and the highest protein to [$Na^+$] ratio. This suggests that a high intracellular $K^+$ content is required for optimum protein synthesis and/ or content. Interestingly, there seems to be a sharp distinction between the high protein animal and the high protein plant tissues in their protein to [$K^+$] and protein to [$Na^+$] ratios. Animals and plants obviously may differ in their metabolic and physiologic requirements for these cations.

We hypothesize that reduction in cellular $Na^+$/ $K^+$-ATPase activity occurred as a result of reduced intracellular $Mg^{2+}$ concentration (Table 2). This might be responsible for the increased [$Ca^{2+}$], [$Na^+$] and the reduced [$K^+$] in our samples. This may explain the immobilization-of-$Ca^{2+}$-in-plant-cell phenomenon described by [1]. Reduction in intracellular [$K^+$] may equally be responsible for the low protein contents of the samples relative to the animal tissues and soybean presented. The results suggest that perturbation of cellular $Na^+$/ $K^+$-ATPase activities by low intracellular [$Mg^{2+}$] may lead to increased intracellular [$Ca^{2+}$] and [$Na^+$] and consequently reductions in intracellular [$K^+$]. The low [$K^+$] engendered effects on cellular metabolism and physiology consequent from downstream effects of immobilization of intracellular $Ca^{2+}$, inhibition of protein synthesis and low protein contents relative to those of the animal tissues and soybean. For instance, a sharp increase in the [$K^+$]/[$Na^+$] ratio by a factor of more than 1472 and sharp decreases in the [$Na^+$]/[$Mg^{2+}$] and [$Na^+$]/[$Ca^{2+}$] ratios by factors more than 193 and 44, respectively, as presented by soybean, relative to our samples (Table 3), may promote protein synthesis and/ or stabilization. It would appear that protein synthesis or level is enhanced in plants when intracellular [$K^+$]/[$Na^+$] ratio increases markedly (Table 3) and a low protein to [$K^+$] ratio is obtained (Table 5). The importance of $K^+$ in plant physiology is borne out in commercial fertilizers like NPK – enriched in nitrogen, phosphorus and potassium. Nitrogen and phosphorus are required in various macromolecular and biomolecular syntheses while $K^+$ serves as a co-factor.

A distinction was also established between plant liquid products, represented by our samples, and plant solid products, represented by the legumes, in their cation profiles (Table 2). While the liquids resemble of the mineral profile of extracellular/ interstitial fluids in their monovalent cation contents, the legumes resemble of the mineral profile of the cytoplasm. Our samples and cow milk also have divalent cation profiles for $Ca^{2+}$ and $Mg^{2+}$ as also found extracellularly. The legumes have divalent cation profiles for $Ca^{2+}$ and $Mg^{2+}$ as found intracellularly in accordance with extracellular [$Ca^{2+}$] > [$Mg^{2+}$] while the reverse is the case, intracellularly.

## Conclusion

The study suggests important insights for the basic understanding of the influence of cellular mineral profiles on protein contents. We proffer a rule that a low $[K^+]/[Na^+]$ ratio (< 1.0) in any plant tissue (and possibly animal tissues as well) indicates a low protein content. This suggests practical applications that may lead to protein enrichment of low protein foods sources through genetic engineering.

**Acknowledgement:** We are grateful to Professor S.E. Okeke, a plant taxonomist, of the Department of Plant Science and Biotechnology, Imo State University, Owerri, Nigeria, for authenticating the leaves of *Terminalia* species.

**Conflict of Interests:** The authors do not have any conflict of interests.

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