Determination of Potassium in Foodstuffs Consumed in Mamuju Indonesia by Neutron Activation Analysis

A H As’ari, S Yusuf, and T R Mulyaningsih
Center for Science and Technology of Advanced Materials, National Nuclear Energy Agency, Kawasan Nuklir Serpong, Setu, Tangerang Selatan, Indonesia

E-mail: ahmad.hasan@batan.go.id

Abstract. Potassium (K) is an essential nutrient and one of the main minerals in the blood as a counterweight to electrolyte and blood pressure. Decreasing K intake can be one of the causes of increased blood pressure. Mamuju is one area with high hypertension cases. Potassium is widely obtained from foodstuffs. In this study, food was collected from the markets in Mamuju Indonesia and analyzed using neutron activation analysis to determine K concentration. The results for the meat and egg category show that beef has a higher potassium concentration than chicken meat, and Negeri chicken eggs are higher than Kampung chicken eggs. For the vegetable category, six samples have very high concentrations of potassium, namely caisim, kemangi, fern leaves, chinese cabbage, spinach, and beans; and the spices namely turmeric and kencur have high concentrations of potassium. For the fish and seafood category, tilapia has the highest potassium concentration and the lowest shrimp. For staples, the highest concentration of potassium is found in potatoes, the lowest in sticky rice; and the processed soybeans, tempeh has a higher potassium concentration than tofu. Therefore, it is important to pay attention to daily potassium intake by looking at the combination of food and potassium concentration in it, such as by increasing consumption of vegetable foods. On the other hand, high potassium intake needs to be followed by a reduction in sodium and salt intake in food.

1. Introduction
Potassium is an essential nutrient mineral in the body. Potassium plays a role in regulating electrolyte fluid balance and controlling the electrical activity of the heart and other muscles. High potassium intake can reduce blood pressure, prevent stroke, cardiovascular disease, and coronary heart disease [1–3]. The World Health Organization (WHO) reports that the recommended minimum intake (adequate intake) of potassium is 3510 mg/day for adults and children, even the Institute of Medicine (IOM) and the US Department of Health and Human Services suggest the increasing for adequate intake of Potassium 4700 mg/day [4,5]. Potassium intake is mostly obtained through foodstuffs, so the combination of foodstuffs with adequate intake of potassium is crucial.

Mamuju is one area with high cases of hypertension. In 2017, there were 407 cases of hypertension in the North Mamuju region. The percentage of hypertension in men reaches 12.53%, whereas in women it reaches 9.42% [6]. Therefore, in this study, food samples were taken in Mamuju randomly. Samples of various types of food that are commonly consumed by the public were purchased from markets in the Mamuju area. Potassium concentration is measured from each type of food to see its distribution.
Several methods such as AAS [7], ICP-MS [8], laser-induced breakdown spectroscopy (LIBS) [9] are widely used for elemental analysis in foodstuffs. In this study, we used the neutron activation analysis (NAA). NAA is a sensitive analytical technique useful for performing both qualitative and quantitative multi-element analysis in samples. It is accurate and reliable. NAA is widely used for elemental analysis in various fields such as archaeology [10], geology [11], biology [12], and food [13].

2. Materials and Methods

2.1. Sample collection
All food samples were collected from Mamuju, West Sulawesi, Indonesia by random sampling. The sample includes various types of food, such as meat, eggs, fish, vegetables, staple foods, and others. Each sample is kept fresh in the freezer before further preparation is carried out.

2.2. Sample preparation and irradiation
All samples were cleaned and washed with running water. The cleaned samples cut into small pieces and put into plastic clips that have been coded. The sample was frozen and put into individual bottles for the freeze-drying process using a freeze dryer (Snijder Scientific, USA) with the pressure of 0.025 Pa and the temperature of 90 °C for 72 hours to remove its water content. The dried samples were mashed using mortar for homogeneous powder (100 mesh in size). Samples and SRM (±100 mg, respectively) were weighed using sartorius M2P microbalance and put into LDPE vials (low-density polyethylene). SRM 1547 (Peach leaves) and SRM 1573a (Tomato leaves) purchased from the National Institute of Science and Technology (NIST, USA) were used as comparators for quality assurance in terms of accuracy, reliability, and relative standard deviation. Al-0.1% Au (close to 3 mg) purchased from the Institute for Reference Material and Measurement (IRRM, Belgium) was used as a neutron flux monitor. The sample, SRM, and flux monitor were wrapped in aluminum foil and arranged into the same irradiation target. The target was put into the irradiated capsule of polyethylene. The irradiation was carried out at the rabbit system facility located in the Multi-purpose Reactor G.A. Siwabessy with a thermal neutron flux of 5x10^13 neutron.cm^-2.s^-1. Radionuclide parameters, γ energy, half-life, and other detailed analysis are presented in Table 1.

Table 1. Analysis parameters of the elements of interest.

| Radionuclide | Element | Half time (h) | γ energy (keV) | Irradiation time (min) | Decay time (d) |
|--------------|---------|---------------|----------------|------------------------|----------------|
| 40K          | K       | 12.36         | 1524.6         | 15-30                  | 2-3            |

2.3. Gamma-ray spectrometry
After reaching the decay time, all samples, SRM, and flux monitor were analyzed by gamma spectrometry (Canberra, USA) using a high purity germanium detector (HPGe) with a relative efficiency of 30% and a resolution of 1.63 keV for a peak of 1332.5 keV of 60Co. Energy calibration in the system is carried out using two radionuclide sources, Cs-137 and Co-60, to cover the energy range of 661 keV to 1332.5 keV. All samples were counted with a counting time of 1800-3600 s. Qualitative analysis was performed with Genie2000 and Hipermate software, while quantitative analysis was carried out with k0-IAEA software.

2.4. Internal quality control
To check the reliability of this method, we use SRM 1547 and SRM 1573a as Quality Control/Quality Assurance. The aim is to assess the quality of the performance of our laboratory. We evaluated our laboratory performance using three statistical parameters: U-test score, Z-score, and relative standard deviation (RSD,%) commonly used. The evaluation uses the U-test score to...
determine the uncertainty of the measurement against the reference. U-test score is calculated using equation 1.

\[ U_{\text{score}} = \frac{|x_m - x_r|}{\sqrt{\mu_m^2 + \mu_r^2}} \]  

(1)

where \( x_m, \mu_m, x_r, \) and \( \mu_r \) are the measurement values, measurement uncertainties, the assigned values, and standard uncertainties, respectively. Z-score indicates a measure of the proximity of the measurement value to the assigned value. The Z-score value is calculated using equation 2.

\[ Z_{\text{score}} = \frac{x_m - x_r}{\mu_r} \]  

(2)

where the laboratory performance is evaluated as satisfactory for \( Z_{\text{score}} \leq 2 \), questionable for \( 2 < Z_{\text{score}} < 3 \), and unsatisfactory for \( Z_{\text{score}} \geq 3 \). RSD is a measure of the type of error called random error, the type of error that cannot be controlled very well [14,15].

3. Results and Discussions

The values of three statistical parameters from our laboratory performance are presented in Table 2.

Table 2. Comparison of the concentration value of the measurement results and the value of the certificate on the SRM.

| Element       | Measured value (mg/kg) | Certified value (mg/kg) | Ratio | RSD | U-test score | Z-score | SRM          |
|---------------|------------------------|-------------------------|-------|-----|--------------|---------|--------------|
| K            | 23945                  | 424                     | 24300 | 300 | 0.99         | 1.5     | Peace leaves |
| K            | 27221                  | 611                     | 27000 | 500 | 1.01         | 0.8     | Tomato leaves|

Table 2 shows that the U-test values were 0.68 and 0.28 (<1.64). This result means that there is no significant difference between the value of the measurement results with the value of the certificate [16]. The evaluation based on Z scores gives values of 0.07 and 0.04 (≪2) respectively, indicate that laboratory performance is satisfactory. The calculation result of the RSD of the measurement is less than 2%. This result shows that its accuracy was satisfactory, indicating that the measured and certified values did not differ significantly [17].

Table 3. Potassium concentration in food samples.

| Samples                  | K concentration (mg/kg) | Samples                  | K concentration (mg/kg) |
|--------------------------|-------------------------|--------------------------|-------------------------|
| Bean                     | 32269                   | Long beans               | 22837                   |
| Phaseolus vulgaris       | 846                     | Vigna unguiculata ssp. Sesquipedalis | 581 |
| Beef                     | 12091                   | Mackerel                 | 10881                   |
| Bos primigenius taurus   | 482                     | Scomber japonicus        | 1108                    |
| Black sticky rice        | 3784                    | Milkfish                 | 10409                   |
| Oryza sativa var glutinosa | 179                   | Chanos chanos            | 425                     |
| Indian mackerel (kembung fish) | 10988              | Moringa leaves           | 16724                   |
| Rastrelliger faugnhi     | 1116                    | Moringa oleifera         | 454                     |
| Cabbage                  | 13434                   | Parrot fish              | 18960                   |
|                          | 571                     |                          | 723                     |
| Food Item                                      | Quantity | Protein | Food Item                                      | Quantity | Protein |
|-----------------------------------------------|----------|---------|-----------------------------------------------|----------|---------|
| Brassica oleracea var. capitata               | 10896    | 512     | Oreochromis niloticus                          | 6225     | 158     |
| Cassava Manihot esculenta                    |          |         | Peanuts Arachis hypogaea                      |          |         |
| Cassava Manihot esculenta                    | 22863    | 679     | Potato Solanum tuberosum                      | 22900    | 1056    |
| Cauliflower Brussica oleracea var. botrytis   | 22541    | 740     | Red corn Zea mays                             | 14288    | 365     |
| Celery leaves Apium graveolens                | 25919    | 1647    | Red onion Allium oschaninii                   | 8745     | 309     |
| Caisim Brussica chinensis var. parachinensis  | 58948    | 1757    | Red snapper fish Lutjanus bohar               | 15452    | 606     |
| Chayote Sechium edule                         | 18233    | 483     | Rice Oryza sativa                             | 1039     | 58      |
| Chicken meat Gallus gallus domesticus         | 9725     | 399     | Shrimp Caridea                                | 5100     | 403     |
| Chinese cabbage Brassica rapa subsp. Pekinensis | 48108   | 1229    | Soybeans Glycine max                          | 13902    | 679     |
| Cob fish Euthynnus affinis                   | 13847    | 887     | Spinach Amaranthus                            | 38716    | 1011    |
| Cutchery Kaempferia galanga                  | 32957    | 850     | Squid Decapodiformes                          | 9499     | 434     |
| Domestic chicken eggs Gallus domesticus       | 6050     | 694     | Sticky rice Oryza sativa var. glutinosa       | 622      | 31      |
| Eggplant Solanum melongena                   | 909      | 24      | Tempeh                                        | 4829     | 139     |
| Fern leaves Diplazium esculentum             | 49339    | 1473    | Tilapia (mujair) fish Oreochromis mossambicus | 10540    | 1047    |
| Garlic Allium sativum                        | 19042    | 482     | Tofu                                          | 1026     | 29      |
| Ginger Zingiber officinale                   | 15254    | 402     | Tomato Solanum lycopersicum                   | 19568    | 841     |
| Green beans Vigna radiata                   | 15954    | 816     | Turmeric Curcuma longa                        | 33628    | 865     |
| Grouper fish Epinephelinae                   | 10195    | 682     | Village chicken eggs Gallus gallus domesticus | 4212     | 328     |
| Kaneke fish Plectortinhchus                  | 8915     | 595     | Water spinach Ipomoea aquatica               | 23686    | 2344    |
| Katuk leaves Sauropus androgynus             | 9642     | 287     | White sweet potato Ipomoea batatas           | 15219    | 383     |
Food samples in Table 3 are grouped into four categories. The first one is the meat and egg category. The result shows that beef has higher potassium concentration than chicken meat, and potassium concentration in Negeri chicken eggs is higher than in Kampung chicken eggs. Distribution of potassium concentration from the first category can be seen in Figure 1.

![Figure 1](image)

**Figure 1.** Distribution of potassium concentrations in the meat and egg category.

The second category, vegetables and spices, has a relatively higher potassium concentration than the other categories, except eggplants which have a low concentration of potassium only (909 ± 24) mg kg⁻¹. There are six vegetables with a concentration of potassium more than the mean value (~27,195 mg kg⁻¹), sequentially the smallest are beans (32,269 ± 846) mg kg⁻¹, spinach (38,716 ± 1011) mg kg⁻¹, Chinese cabbage (48,108 ± 1229) mg kg⁻¹, fern leaves (49,339 ± 1473) mg kg⁻¹, kemangi (54,703 ± 1605) mg kg⁻¹, and caisim (58,948 ± 1757) mg kg⁻¹. Turmeric and kencur, which are commonly used as spices, also have high enough potassium concentrations of more than 30,000 mg kg⁻¹. Distribution of potassium concentration from vegetables and spices category can be seen in Figure 2.
Figure 2. Distribution of potassium concentrations in the vegetables and spices category.

The third category, fish and seafood, contains potassium which is not far adrift between samples. Tilapia has the highest potassium concentration of \((18,960 \pm 723) \text{ mg kg}^{-1}\), and shrimp has the lowest potassium concentration of \((5,100 \pm 403) \text{ mg kg}^{-1}\). The potassium concentration between sea fish and freshwater fish is not significantly different. Distribution of potassium concentration from the third category can be seen in Figure 3.

Figure 3. Distribution of potassium concentrations in the fish and seafood category.

The last category, staples and preparations, has a variety of potassium content. Rice as a staple food for the majority of Indonesian people has a low potassium concentration of \((1,039 \pm 58) \text{ mg kg}^{-1}\), while potatoes had a high potassium concentration of \((22,900 \pm 1056) \text{ mg kg}^{-1}\). In the world, rice as a staple food contributes to food energy supply by 20%, while corn and potatoes contribute 5% and 2% [18]. The use of potatoes as a staple food is widely consumed in developed countries, such as Russia, UK,
Ukraine, Belarus, Portugal, and countries in the Commonwealth of the Independent States that depend heavily on potatoes for their energy consumption [19]. For processed soy products, tempeh has a higher potassium concentration than tofu.

**Figure 4.** Distribution of potassium concentration in the staple food and its derivatives category.

The level of consumption of some foodstuffs in a day by the Indonesian people can be seen in Table 4. Several foodstuffs have a relatively high level of consumption followed by high enough potassium concentration, such as rice, chicken, meat, various types of fish and shrimp, and tempeh. On the other hand, several foodstuffs have a low consumption level but have relatively high potassium concentration, such as potatoes, sweet potatoes, cassava, cassava leaves, tomatoes, Chinese cabbage, water spinach, spinach, long beans, and other vegetables. Therefore, it is important to pay attention to daily potassium intake by looking at the combination of food and potassium concentration in it, such as by increasing consumption of vegetable foods.

**Table 4.** The level of consumption of some foodstuffs and estimated daily potassium intake [20,21]

| Foodstuffs          | Consumption rate per day (kg) | Estimated daily potassium intake (mg) |
|---------------------|------------------------------|---------------------------------------|
| Beef                | 0.0013                       | 16                                    |
| Chicken meat        | 0.0173                       | 168                                   |
| Kampung chicken egg | 0.0006                       | 2                                     |
| Negeri chicken egg  | 0.0010                       | 6                                     |
| Red onion           | 0.0076                       | 66                                    |
| Garlic              | 0.0047                       | 90                                    |
| Soybean             | 0.0001                       | 2                                     |
| Long bean           | 0.0064                       | 147                                   |
| Spinach             | 0.0090                       | 348                                   |
| Bean                | 0.0026                       | 83                                    |
| Leek                | 0.0004                       | 5                                     |
| Cabbage             | 0.0040                       | 54                                    |
In its function as a blood pressure-lowering, an increase in potassium intake needs to be followed by a reduction in sodium intake in food. Addition of salt in food also needs to be avoided so that sodium intake does not exceed the maximum intake limit per day of 2 g/day sodium (5 g/day salt) [22].

4. Conclusion
The results for the meat and egg category show that beef has a higher potassium concentration than chicken meat, and Negeri chicken eggs are higher than Kampung chicken eggs. For the vegetable category, six samples have very high concentrations of potassium, namely caisim, kemangi, fern leaves, Chinese cabbage, spinach, and beans; and the spices namely turmeric and kencur have high concentrations of potassium. For the fish and seafood category, tilapia has the highest potassium concentration and the lowest shrimp. For staples, the highest concentration of potassium is found in potatoes, the lowest in sticky rice; and the processed soybeans, tempeh has a higher potassium concentration than tofu. Therefore, it is important to pay attention to daily potassium intake by looking at the combination of food and potassium concentration in it, such as by increasing consumption of vegetable foods. On the other hand, high potassium intake needs to be followed by a reduction in sodium and salt intake in food.

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