ROLE OF POTASSIUM IN HUMAN AND ANIMAL NUTRITION

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DAR ES SALAAM
OUTLINE

- Introduction
- Functions of potassium in the body
- Sources of potassium in the diet
- Potassium content of foods in Tanzania
- Recommended intake of potassium for optimal nutrition
- Effect of deficiency and excess intake of potassium
- Factors influencing availability of potassium in foods
- Factors influencing potassium availability in the body
INTRODUCTION

- Potassium is a light soft silver-white metallic chemical element of the alkali metal group presented as symbol K
- Oxidises rapidly in air and reacts violently with water
- Atomic number 19; means it has 19 electrons (2:8:8:1)
- Atomic weight 39.098;
- Ability to loose an extra electron and acquire an over all +VE charge than to gain one and acquire a negative charge.
- Most of its functions are based on this overall +VE charge
PERIODIC TABLE OF THE ELEMENTS

The Periodic Table is a systematic arrangement of the chemical elements according to their atomic structure. The elements are arranged so that their atomic numbers—the number of protons in each element's nucleus—increase as you read across each row from left to right. Thus hydrogen (atomic number 1) comes first in the Table, helium (atomic number 2) comes second, lithium (atomic number 3) comes third, and so on.

The first Periodic Table was designed by Dmitri Mendeleev in 1869. At that time only 63 of the elements were known. Today we know a total of 112. When Mendeleev made the first table he knew that other elements would eventually be discovered, and he left empty spaces so that the new elements could be added as they were found.

Periods

The elements are placed into seven rows, or periods, according to the number of electron shells in their atoms. Each atom consists of a nucleus of neutrons and protons surrounded by one or more energy levels, or shells, in which electrons are continuously orbiting. The smallest atoms have only one electron shell. Larger atoms have as many as seven shells, each one successively larger than the one inside it. Hydrogen and helium have only one electron shell and are therefore placed in Period 1, while sodium and chlorine have three shells and are placed in Period 3. By noting the period in which an element is located, you can immediately know how many electron shells it has.

Lanthanides and Actinides

The elements of the lanthanide series (elements 57–71) and the actinide series (elements 89–103) all behave in a manner similar to that of the elements in Group 3. But since they have different atomic numbers, they are separated from the main Periodic Table to make it easier to read.

Groups

The elements are organized into 18 separate columns, or groups, according primarily to the number of electrons occupying their outermost shell. This number is important because it strongly affects the way an element will behave in a chemical reaction. Since the elements in each group have the same number of electrons in their outer shell, they share certain chemical behaviors such as the ability to combine with other elements to form compounds. In the case of the larger elements in Periods 4 through 7, the number of electrons in some of the inner shells also affects their behavior and thus determines where their groups are placed in the Table.

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INTRODUCTION

- Potassium is a mineral found in foods
- It is also an electrolyte, which conducts electrical impulses throughout the body
- It is an essential nutrient because it is not produced naturally by the body
- Therefore it is important to consume the right balance of potassium-rich foods and beverages
- This nutrient has not been considered as an important nutrient in nutrition
BIOCHEMICAL FUNCTIONS OF POTASSIUM

- Potassium is one of the highest common elements/minerals (by mass) in the human body (0.2%) (70 kg = 140 g) after calcium and phosphorus

- Potassium assists in a range of essential body functions, including:
  - To maintain body fluid and electrolyte balance
    - Body fluid: about 50-70% (42 litres) of an adult body weight is made up of fluid
    - 28 litres is within the cells - intracellular fluid and 14 litres is outside the cell - extracellular fluid.
  - There are two types of extracellular fluid:
    1. Tissue fluid or interstitial (flows between cells). Also includes cerebrospinal, mucus and synovial.
    2. Intravascular fluid - plasma, which contains large proteins
BIOCHEMICAL FUNCTIONS OF POTASSIUM....

- Body fluid is composed of water and electrolytes
- Water: dissolves and transport substances, account for blood volume, maintain body temperature, protect and lubricate tissues
- Electrolytes (Potassium K\(^+\), Sodium Na\(^+\), Chloride Cl\(^-\) & Phosphorus HPO\(_4^{2-}\)), form ions when dissolve in water and are capable of carrying an electrical current. The electrical charge acts as a “spark” that stimulates nerves and causes muscles to contract.
- K\(^+\) and HPO\(_4^{2-}\) are dominant in the intracellular fluid and Na\(^+\) and Cl\(^-\) in the extracellular. The occurrence of these electrolytes on either side of the cell membrane creates a difference in electrical charge and this is needed in order for the cell to perform its normal functions.
Regulation of electrolyte balance: Water flows to an area where the level of electrolytes is high therefore controls movement of fluid into and out of the cells.

Cells regulate the balance of fluids between internal and external environments by using special transport proteins that actively pump *potassium* and sodium across cell membranes.
Cells contain a relatively high concentration of potassium ions but low concentrations of sodium ions. Most of the sodium ions are in the extracellular fluid compartment. The sodium-potassium pump moves two ions in opposite directions across the plasma membrane. The two sides of the membrane are interdependent. The protein carrier ATP-ase transports both ions. The pump pumps three sodium ions out of the cell for every two potassium ions pumped into the cell. The balance between sodium and potassium creates an electrical and chemical gradient that functions to transport molecules in and out of the cell and transmit nerve signals that induce muscle contraction and induce functions related to muscles.
MAINTENANCE OF FLUID BALANCE

- **Mechanisms:**
  A. Thirst: A desire to drink fluids in response to an increase in the concentration of $\text{Na}^+$ in the blood or decrease in blood pressure and volume
  - Increased salt concentration ($\text{Na}^+$) in the blood. Water moves from the cell into the ECF
  - Reduction in blood volume and blood pressure (vomiting, sweating, blood loss, diarrhoea and low fluid intake)
  - Dryness in tissues of the mouth and throat
In neural cells, electrical potentials are created by the separation of positive and negative electrical charges that are carried on ions (charged atoms) across the cell membrane.

Resting state or potential: The intracellular fluid has slightly more electrolytes with a negative charge ($K^+$ and $HPO_4^{2-}$).

The Nerve cell membrane is in the polarised state. There is a balance between charges on either side of the membrane.
NERVE IMPULSE TRANSMISSION

- Nerve Stimulation: A stimulus causes an influx of sodium into the interior of the cell through Na+ gates.
- The charge inside the cell becomes **positive and outside negative**; the cell membrane is depolarised.
- An action potential is transmitted to adjacent regions of the cell membrane.
- This causes an imbalance in the concentration of ions, which prompts the movement of potassium ions to try to restore the balance.

b) Depolarization
NERVE IMPULSE TRANSMISSION

- Repolarisation: Release of potassium to the exterior of the cell allows the first portion of the membrane to return to the resting state until next stimulation.
- In the absence of potassium, this sequence of events will not take place and therefore no nervous impulse transmission can occur.
MUSCLE CONTRACTIONS

- Electrolytes are especially important for normal contraction of skeletal and cardiac muscle fibres. Without the appropriate balance of electrolytes such as potassium and sodium, heart contractions become abnormal and the risk of heart attack increases.
- Potassium is crucial to heart function, and low levels in the body (hypokalemia) lead to irregular contractions and abnormal electrocardiograms.
- Potassium is needed to work in the outer membranes of cardiac muscle cells.
- These channels open in response to a change in voltage and are responsible for terminating action potentials and contractions while initiating repolarization.
- Hyperkalemia -- too much potassium in the body -- causes reduced electrical conduction and often leads to palpitations and disrupted heart rhythm.
MUSCLE CONTRACTIONS...

- The electrical impulse generated by potassium stimulates calcium ions to move across the cell membrane to the fluid surrounding the cell. This movement of calcium ions triggers the muscle cells to contract and aids in movement.

- A low potassium level inhibits muscle relaxation, causing rigid muscles that lead to tension and impaired function.

- Common symptoms of potassium deficiency include muscle weakness and spasms.
BLOOD PRESSURE

- Blood pressure is influenced by the dietary potassium intake, both in normal subjects and hypertensive subjects.

- The increased prevalence of high blood pressure in the population does not appear to be related to greater dietary intake of sodium chloride but rather due low potassium intake.

- Dietary potassium depletion raises blood pressure in normal humans
Potassium is a vasodilator and has a relaxation effect on the tiny blood vessels called arterioles and this results in increased local blood flow.

Low level of potassium leads to vasoconstriction and increased blood pressure.

Excessive sodium consumption results in urinary potassium loss and increased blood pressure.

Kidneys help to control blood pressure by controlling the amount of fluid stored in the body. The more fluid, the higher the blood pressure.

Kidneys do this by filtering the blood to remove the extra fluid and stores it as urine in the bladder.

This process requires a delicate balance of sodium and potassium in order to absorb water across a wall of cells from the bloodstream into a collecting channel that leads to the bladder.
GASTROINTESTINAL MOTILITY

- Digestion process is facilitated by rhythmic intestinal contractions called peristalsis responsible for propelling the food along the GIT.
- Peristalsis involves alternating contraction and relaxation of the smooth muscle tissue in the walls of the intestines and pushes the contents of the tract forward.
- The muscles of the intestines rely on potassium and other minerals such as sodium, calcium and magnesium for normal tone to facilitate contraction.
- Hypokalemia (low potassium) negatively affect peristalsis and lead to stomach upset, abdominal cramps, constipation and even intestinal paralysis.
- It is estimated that one in three persons has a GI functional or motility disorder (not sure about the prevalence in Tanzania since these cases are never diagnosed and reported).
Other Functions

- Glucose and insulin metabolism
  - Potassium, (serum and extent dietary intake levels), has been associated with incident of diabetes.
  - Lower levels of potassium have been found to be associated with a higher risk of diabetes through interference on the functioning of beta cells.
  - Hypokalemia lead to impaired glucose tolerance by reducing insulin secretion in response to glucose loads as well as interruption on glucose transportation at the cell membrane.

- Hormone secretion

- Control electrical activity of the heart

- Renal concentrating ability

- Mineral-corticoid action

- Body Growth and Development

- Activate enzymes

- Metabolism of carbohydrates and proteins
SOURCES OF POTASSIUM IN THE DIET

- Potassium occurs in all living cells. Therefore it is present in all plants (crops) and animals
  - Meat and meat products
  - Dairy and dairy products
  - Green leafy vegetables and non leafy vegetables, mushrooms
  - Legumes
  - Roots and tubers (potatoes and sweet potatoes)
  - Fruits - bananas, kiwi, citrus fruits, avocado
  - Nuts
RECOMMENDED INTAKE OF POTASSIUM FOR OPTIMAL NUTRITION

- The proper level of potassium is essential for normal cell function. An abnormal increase in potassium (hyperkalemia) or decrease in potassium (hypokalemia) can profoundly affect the nervous system and heart, and when extreme, can be fatal. The normal blood potassium level is 3.5 to 5.0 milliEquivalents/liter (mEq/L), or 3.5 international units (3.5 - 5.0 mmol per litre of plasma).

- Levels below or higher than these normal levels are associated with increased rate of death of any cause. Cardiac, kidney and lung diseases are accelerated if serum potassium levels are not maintained within the normal range.

- A healthy diet should include 4,700 milligrams of potassium each day.

- In nutrition, we have no been paying attention either on this nutrient.

- No recommended intake levels for Tanzania population or even prevalence of deficiency.
DIGESTION AND ABSORPTION

• The absorption of potassium takes place in the intestinal tract.

• Potassium absorption occurs in the portions of the intestine called the ileum and the jejunum.

• It is a passive process, therefore potassium diffuses into the blood on its own according to the concentration gradient.
# Potassium Content of Foods in Tanzania

<table>
<thead>
<tr>
<th>Food Item</th>
<th>K (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize flour</td>
<td>287</td>
</tr>
<tr>
<td>Bulrush millet</td>
<td>307</td>
</tr>
<tr>
<td>Finger millet</td>
<td>408</td>
</tr>
<tr>
<td>Rice</td>
<td>81</td>
</tr>
<tr>
<td>Sorghum</td>
<td>131</td>
</tr>
<tr>
<td>Wheat</td>
<td>107</td>
</tr>
<tr>
<td>Cowpea</td>
<td>278</td>
</tr>
<tr>
<td>Pigeon pea</td>
<td>777</td>
</tr>
<tr>
<td>Cassava</td>
<td>243</td>
</tr>
<tr>
<td>Sweet potatoes</td>
<td>303</td>
</tr>
<tr>
<td>Beans</td>
<td>1036</td>
</tr>
<tr>
<td>Bambara</td>
<td>539</td>
</tr>
<tr>
<td>Chickpea</td>
<td>291</td>
</tr>
<tr>
<td>Cowpea</td>
<td>278</td>
</tr>
<tr>
<td>Lentil</td>
<td>303</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>705</td>
</tr>
<tr>
<td>Cashewnute</td>
<td>732</td>
</tr>
<tr>
<td>Beef</td>
<td>230</td>
</tr>
<tr>
<td>Fish</td>
<td>122</td>
</tr>
</tbody>
</table>
POTASSIUM CONTENT OF FOODS IN TANZANIA.....

<table>
<thead>
<tr>
<th>Food</th>
<th>Potassium Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baobab</td>
<td>1221</td>
</tr>
<tr>
<td>Banana</td>
<td>385</td>
</tr>
<tr>
<td>Bread fruit</td>
<td>490</td>
</tr>
<tr>
<td>Guava</td>
<td>417</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>303</td>
</tr>
<tr>
<td>Orange</td>
<td>181</td>
</tr>
<tr>
<td>Tamarind</td>
<td>676</td>
</tr>
<tr>
<td>Papaya</td>
<td>257</td>
</tr>
<tr>
<td>Cassava leaves</td>
<td>550</td>
</tr>
<tr>
<td>Spinach</td>
<td>466</td>
</tr>
<tr>
<td>Carrot</td>
<td>320</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>315</td>
</tr>
<tr>
<td>Mushroom</td>
<td>318</td>
</tr>
<tr>
<td>Okra</td>
<td>304</td>
</tr>
<tr>
<td>Okra</td>
<td>304</td>
</tr>
<tr>
<td>Cowpea</td>
<td>248</td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>202</td>
</tr>
</tbody>
</table>

http://www.hsph.harvard.edu/nutritionsource/more/food-tables/index.html
DEFICIENCY OF POTASSIUM

- Hypokalemia: Cause GI loss due to vomiting and renal loss due to diuresis
  - Symptoms
    - muscle weakness,
    - paralytic ileum
    - ECG abnormalities
    - Decreased reflex response
    - Respiratory paralysis
    - Cardiac arrhythmia

- Hyperkalemia: is the medical term that describes a potassium level in the blood that's higher than normal.
  - Symptoms:
    - malaise, palpitations and muscle weakness, mild hyperventilation may indicate a compensatory response to metabolic acidosis, which is one of the possible causes of hyperkalemia
FACTORS INFLUENCING POTASSIUM AVAILABILITY IN FOODS

- **Soil test K:** Higher soil test K increases the available K, by increasing the amount and balance of K relative to other cations.

- **Cation Balance:** Where there is a significant imbalance between available K and the other major cations (Primarily Calcium, Magnesium, and sometimes Hydrogen, Aluminum, or Sodium), it may affect the availability of K to the crop.

- **Soil Moisture:** K is transported within the soil and is absorbed by plant roots in the soil water. Therefore a water deficiency results in less K absorption.

- **Soil pH:** As the soil pH is reduced (increasing soil acidity) the availability of K is often reduced.

- **Soil Temperature:** Cold soils often reduce the availability of K.

- **Soil compaction:** Compacted soils often reduce the availability of K.

- **Soil Drainage/Aeration:** As soil drainage is improved, K uptake typically improves.

- **Soil Salinity:** Saline soils often have excess sodium (Na). One of the negative effects of excess Na is that it reduces the availability of K.

- **Interactions**
  - **K/Mg ratio:** Each of K or Mg can reduce the uptake of the other when the "normal" soil balance does not exist.

- **Soil CEC**
FACTORS INFLUENCING POTASSIUM AVAILABILITY IN THE BODY

- Presence of substances that inhibit absorption, transportation and utilisation of potassium
- Deficiency of protein that may interfere with movement of potassium into and outside the cell
CONCLUSION

- Potassium is the chief intracellular cation

- Relative intracellular-extracellular potassium concentrations directly affects a cell's resting membrane potential, therefore a slight change on either side of the membrane has profound effects (e.g. on neurones and muscle fibres)

- Potassium is part of the body's buffer system, which resists changes in pH of body fluids; ECF potassium levels rise with acidosis (decrease pH) as potassium leave cells and fall with alkalosis (increase pH) as potassium moves into cells

- Potassium balance is maintained primarily by renal mechanisms (i.e. influenced by Aldosterone)

- Potassium reabsorption from the filtrate is constant - 10-15% is lost in urine regardless of need; because potassium content of ECF is low (compared to sodium concentration), potassium balance os accomplished by changing amount of potassium secreted into the filtrate; therefore regulated by collecting tubules
CONCLUSION

- Potassium is crucial for human as well as animal nutrition and foods are the good sources of the mineral.

- The mineral is essential because the body has no ability of making potassium for its requirement.

- Crops obtain potassium from the soil, it is crucial that the soils in which food crops are grown should have sufficient quantities of the mineral.

- As we strive to improve crop productivity we also need to consider nutritional quality of crops.

- Efforts to improve soil fertility should be seen as efforts to improve human health since this is our overall goal. Soil scientists are urged to consider nutritional quality of crops in soil programmes.
THANK YOU