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IMPROVING RICE NUTRITION THROUGH FORTIFICATION WITH CASSAVA AND SWEET POTATO FLOUR: A PROMISING STRATEGY FOR ADDRESSING MICRONUTRIENT DEFICIENCIES

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Abstract : Fortified rice has gained popularity as an effective means of addressing nutrient deficiencies, particularly in developing countries where access to a diverse and nutritious diet is limited. Cassava and sweet potato are two starchy root vegetables that are rich in nutrients and widely consumed in tropical and subtropical regions. This article explores the benefits and process of fortifying rice using cassava and sweet potato powders, through Hot Extrusion process with a focus on the potential impact of this approach on addressing malnutrition. We review the nutrient content of cassava and sweet potato, and discuss the methods of producing and adding their powders to rice. Additionally, we examine the effectiveness of fortified rice in improving nutrient intake, as well as the challenges and opportunities associated with promoting the consumption of fortified rice. Finally, we conclude by highlighting the potential of fortified rice using cassava and sweet potato powders as a cost-effective, scalable, and sustainable approach to addressing malnutrition in vulnerable populations.

IndexTerms **-Fortified rice, Cassava flour, Sweet potato flour, Fortifications.**

I. INTRODUCTION

Fortified rice, which is rice enriched with additional vitamins and minerals, is an effective way to address malnutrition, especially in developing countries where access to a diverse and nutritious diet is limited. In recent years, there has been growing interest in fortifying rice using cassava powder and sweet potato powder, two starchy root vegetables that are rich in nutrients. Cassava and sweet potato are widely cultivated in tropical and subtropical regions and are important staple foods for millions of people. By adding cassava powder and sweet potato powder to rice, the resulting fortified rice can help to address nutrient deficiencies and improve the overall health and well-being of people who consume it. In this article, we will explore the benefits and process of fortifying rice using cassava and sweet potato powders, and the potential impact this could have on addressing malnutrition. To combat under-nutrition, using locally available food crops in a concentrated manner to provide energy, protein, vitamins, and minerals is an effective strategy [9].

II. AIMS TO ACHIEVE

The main aim of fortification of rice is to increase the nutritional value of rice by adding essential vitamins and minerals to the grains. This is especially important in areas where rice is a staple food and where people may not have access to a varied diet that provides all the necessary nutrients for good health. Fortification of rice typically involves adding micronutrients such as iron, zinc, and B vitamins to the rice grains. This can be done by coating the rice with a nutrient powder, or by using a process called extrusion to incorporate the nutrients directly into the rice grains.

The specific objectives of rice fortification may vary depending on the target population and the specific nutrient deficiencies that are most common in the area. Some common objectives of rice fortification include is reducing the prevalence of micronutrient deficiencies, such as iron deficiency anemia, zinc deficiency, and vitamin B deficiency. Improving overall nutritional status and health outcomes, especially among vulnerable populations such as young children and pregnant or lactating women. Increasing food security by improving the nutritional quality of staple foods and reducing reliance on expensive nutrient supplements. Addressing the social and economic consequences of micronutrient deficiencies, such as reduced productivity and increased healthcare costs. Overall, rice fortification is a cost-effective and sustainable strategy for improving the nutritional quality of rice and addressing micronutrient deficiencies in populations that rely on rice as a staple food. To provide practical guidance for policymakers, food manufacturers, and other stakeholders on how to implement and scale up fortified rice using cassava and sweet potato powders and to call for increased awareness and investment in fortified rice using cassava and sweet potato powders as an important strategy for addressing malnutrition and improving public health.

III. Fortified rice

Fortified rice is a type of rice that has been enriched with additional nutrients to help address nutrient deficiencies, especially in developing countries. Nutrient deficiencies can occur due to a lack of access to a diverse and nutritious diet or due to low absorption of essential vitamins and minerals [1]. Fortified rice is typically enriched with nutrients such as iron, zinc, vitamin A, and folic acid. These nutrients are added to rice through a process called fortification, which involves spraying the rice with a nutrient-rich powder or coating the rice with a nutrient-rich layer or Extruding rice together with a powder that is rich in nutrients. Fortified rice is an important tool in the fight against malnutrition, especially in developing countries where rice is a staple food. By adding essential vitamins and minerals to rice, fortified rice can help provide people with the nutrients they need to support their health and well-being. It can also help prevent a variety of health issues that can result from nutrient deficiencies, such as anemia and blindness. Researchers have also evaluated the effects of adding zinc, folic acid, vitamin B1, and vitamin B12 to rice on micronutrient levels [19].

Fortified rice is safe to eat and does not significantly alter the taste or texture of the rice. It is important to note that while fortified rice can be a valuable tool in addressing nutrient deficiencies, it should not be seen as a substitute for a diverse and nutritious diet that includes a variety of whole foods. Many countries have implemented food fortification programs for several years, and they have been shown to improve the nutritional status of both adults and children. The process usually involves using staple foods as carriers for the lacking nutrient in the population's diet. The key to a successful fortification program is selecting the appropriate fortificant [8]. Many developing countries and international partners prioritize the reduction of under-nutrition and micronutrient deficiencies, as it impacts over 33% of the world's population [9]. Asia is responsible for producing and consuming 90% of the world's rice. Rice makes up approximately 30% of the average person's calorie intake, although this percentage can rise to over 70% in certain low-income countries and international partners prioritize the reduction of under-nutrition and micronutrient deficiencies, as it impacts over 33% of the world's population [9,17].

IV. Hot extrusion

Hot extrusion is one method for fortifying rice with additional nutrients. The process involves adding a nutrient-rich powder to the rice and then processing it through a hot extrusion machine. The hot extrusion machine applies heat and pressure to the rice, causing it to expand and change its structure. Extrusion has been utilized in the food industry since the 1940s and it is classified as a combinatorial process [2]. During the hot extrusion process, the nutrient-rich powder is forced into the rice grains, where it becomes embedded. This helps to ensure that the added nutrients are evenly distributed throughout the rice. The hot extrusion process also causes the rice to become more dense and less porous, which can help to prevent nutrient loss during storage and cooking. The types of nutrients that can be added to rice using the hot extrusion method include iron, zinc, vitamin A, and folic acid. The specific nutrients and their levels can vary depending on the intended use of the fortified rice.

The hot extrusion method is an effective way to fortify rice with additional nutrients, but it requires specialized equipment and technical expertise. The cost of hot extrusion machines and associated equipment can be high, which can be a barrier to implementing this method in some settings. Despite these challenges, the hot extrusion method has been successfully used to produce fortified rice in various settings, including in developing countries where nutrient deficiencies are common. Fortified rice produced using the hot extrusion method has been shown to be an effective way to address nutrient deficiencies and improve the health of populations that consume it regularly.

V. Preparation of flour

The process of preparing tubers to powder typically involves several steps. First, the tubers are washed and cleaned to remove any dirt or debris. Next, they are peeled and sliced into small pieces, which are then dried using methods such as sun-drying, oven-drying, or dehydrating. Once the pieces are completely dried, they are ground into a fine powder using a food processor, blender, or mill. The resulting powder can be stored in an airtight container and used as a nutritional supplement. After being pulverized, the samples were placed in an airtight container and kept at a temperature of -4°C until they were ready to be analysed [9]. The rice flour was fortified by adding 10% and 20% of nutritional flour, based on factors such as production cost and customer acceptance. Previous studies have shown that products fortified with 10% and 20% nutritional flour were generally well received. However, increasing the level of fortification may negatively affect the appearance, taste, and texture of the product [8]. As per the specified standards, the rice grains should have a length of 5 mm and a width of 2.2 mm. In accordance with the ministry's specifications, 10 grams of FRK should be mixed with 1 kilogram of regular rice [20]. The extent of gelatinization was determined by measuring the absorbance of A1/A2 (%).

Additionally, it is crucial to determine the in-vitro and in-vivo digestibility characteristics of the fortified dense dough. This is especially critical as past research has shown that around 70% of the protein present in MOLP is insoluble. The authors of the study reported that MOLP had a low in-vitro protein digestibility of only 33%. The observed low digestibility of MOLP was attributed to the natural resistance of MOLP against digestive enzymes, and the possible presence of heat-resistant substances such as tannins[2]. The previous study shows that the Volunteers evaluated aroma, color, appearance, taste, shine and size of fortified cooked rice using rating 95%, 78%, 85%, 88%, 75% and 77% and 60%, 76%, 85%, 78%, 77%, 70% for non-fortified cooked rice during sensory evaluation.[19].

Determination of Moisture Content

To determine the moisture content, 5 grams of the sample was weighed in an empty Petri dish and recorded as the initial weight (W1). The sample was then dried in an oven preheated to 100°C for 4 to 5 hours. After drying, the sample was placed in a desiccator to cool down before being weighed and recorded as the final weight (W2).

$$\text{Moisture content (\%)} = \frac{W1-W2}{W1} \times 100$$

Determination of Ash Content

The ash content was determined by following the method described in AOAC, 2000. A finely ground sample was weighed (W1) and placed in a pre-weighed silica crucible (W2) marked with "Z". The organic matter was then completely oxidized in a muffle furnace at 550°C for 4 hours, and the resulting ash was weighed (W3).

$$\text{Ash content (\%)} = \frac{W3-W2}{W1} \times 100$$

Determination of Fat Content

The crude fat content was analyzed using the Soxhlet apparatus and procedure outlined in AOAC, 2000. The moisture-free powdered sample was weighed in a thimble and noted as "A," while the empty flask before extraction was weighed and noted as "C." The fat was then extracted from the sample at a temperature of 60-80°C for 6-8 hours. After extraction, the solvent was removed and the flask was reweighed and noted as "C." The fat content was calculated using a formula based on these measurements.

$$\text{Fat content (\%)} = \frac{B-C}{A} \times 100$$

Determination of Protein Content

The protein content was analyzed using the Kjeldhal apparatus. The sample was boiled with concentrated H2SO4 to digest the nitrogen-containing material in the sample and convert it into ammonium sulfate. The resulting mixture was then treated with an excess of alkali to decompose and release ammonia into a solution of boric acid. The ammonia reacted with the boric acid to form ammonium borate, which was titrated directly against a standard solution of HCl.

$$\%\,N = \frac{(\text{ml of sample} - \text{ml of blank}) \times \text{Normality of H2SO4} \times 0.014 \times 100}{\text{ml of aliquot taken for distillation} \times \text{weight of sample (g)}}$$

$$\text{Crude Protein (\%)} = N \times 6.25$$

Determination of Crude Fibre

To determine the crude fiber content, take 2 grams of defatted sample and boil it in a digestion flask with a condenser attached, along with 200 milliliters of sulfuric acid and 0.5 grams of asbestos, for 30 minutes. Filter the resulting mixture and wash the residue with boiling water to remove any remaining acid. Then, wash the residue with a hot 10% potassium sulfate solution and return it to the digestion flask by washing all the residue from the filter cloth with hot water. Filter the mixture into a Gooch crucible using 15 milliliters of alcohol, and dry the contents at a temperature of 1100 C. Cool the crucible in a desiccator and ignite it in a muffle furnace. After cooling the crucible again in a desiccator, the loss in weight represents the crude fiber content.

$$\%\ \text{Crude fibre} = \frac{\text{Loss in weight noted}}{\text{Wt.of sample taken}} \times 100$$

Determination of Carbohydrate

Carbohydrates are present in both simple forms, such as sugars, and complex forms, such as fiber and starches. The determination of carbohydrate content was carried out using a method that involves calculating the difference between the total weight of the sample and the sum of the weights of other macronutrients.

Carbohydrate (%) = 100 - (% Moisture + % Ash + % Fat + % Protein + % Fibre)

VI. CASSAVA

Cassava (Manihot esculenta), also known as yucca or manioc, is a starchy root vegetable that is native to South America but is now cultivated in tropical and subtropical regions around the world. It is a highly profitable crop in terms of food calorie production per unit of area and time, surpassing other staple crops and an important staple food for millions of people, particularly in Africa, Asia, and Latin America. Cassava is a hardy crop that can grow in poor soil and withstand drought, making it a valuable crop in areas where other crops may not thrive. The plant can grow up to three meters tall and produces large, edible, tuberous roots that are usually harvested after 12-24 months of growth. In comparison to other crops, cassava generates over 250,000 food calories per hectare per day, while maize produces 200,000, rice produces 176,000, and wheat produces 110,000 [6].

Cassava roots are rich in carbohydrates, and contain smaller amounts of fiber, vitamins, and minerals. The nutritional content of cassava is influenced by several factors such as the plant part used (leaves or root), variety, age, geographical location, and environmental conditions. The storage roots of cassava are an excellent source of energy, containing between 32% to 35% carbohydrates on a fresh weight (FW) basis and 80% to 91% on a dry matter (DM) basis. Cassava is often consumed boiled, mashed, or fried, and is used in a variety of dishes, including stews, soups, and casseroles. It is also used to make flour, which can be used to make bread, cakes, and other baked goods. Additionally, cassava is used in the production of tapioca, a popular ingredient in desserts and bubble tea. While cassava is a valuable source of carbohydrates, it has low levels of protein and other essential nutrients, which can contribute to malnutrition. However, cassava can be combined with other nutrient-rich foods, such as sweet potato and other vegetables, to create a more balanced and nutritious diet. Cassava can also be used to fortify other foods, such as rice, by adding cassava powder to the food product.

Nutritional value of cassava powder :

Cassava powder is a popular ingredient in gluten-free baking and cooking. It is made from the root of the cassava plant (Manihot esculenta), which is a starchy root vegetable. The amount of fiber present in cassava roots varies depending on the type of cassava and how mature the root is [14]. The nutritional value of cassava powder is similar to that of cassava root, but the nutrient content can vary depending on the brand and how it is processed.

According to the United States Department of Agriculture (USDA) National Nutrient Database, here are the approximate nutrient values for 100g of dry cassava flour:

Table 1 : Cassava Flour

NUTRIENTS	VALUES PER 100g
Calories	356
Moisture	12.5 g
Ash	1.6 g
Protein	1.4 g
Fat	0.3 g
Carbohydrates	85.3 g
Fiber	1.4 g
Calcium	16 mg
Iron	0.27 mg
Magnesium	21 mg
Phosphorus	27 mg
Potassium	271 mg
Sodium	14 mg
Zinc	0.27 mg
Vitamin E	0.19 mg
Vitamin K	1.9 µg
Thiamin	0.087 mg
Riboflavin	0.022 mg
Niacin	0.854 mg
Vitamin B6	0.088 mg
Folate	27 µg

Note : The nutritional composition of a food item can be influenced by several factors, including the quality and type of ingredients used, the processing method employed, and the conditions under which the food is stored. As a result, the nutritional value of a food may differ depending on these variables.

VII. Sweet potato

Sweet potato (Ipomoea batatas) is a root vegetable that is popular all over the world for its sweet taste, versatility, and nutritional benefits.Sweet potato is a significant source of non-rice carbohydrates and is considered one of the top sources of this nutrient after maize and cassava. Its importance in fulfilling global food requirements cannot be understated. Over the last few decades, sweet potato has become increasingly popular, particularly the purple-fleshed variety.[8] Asia and the Pacific Islands are responsible for producing around 92% of the global supply of sweet potato [12]. Sweet potatoes come in a variety of shapes, sizes, and colors, with the most common varieties being orange, white, and purple. Sweet potato (Ipomoea batatas) is considered a super-food due to its high levels of vitamins, fiber, manganese, copper, potassium, and pantothenic acid. Additionally, it is a good source of dietary fiber, niacin, and phosphorus. This crop has the potential to address food security issues, as it contains more vitamins, minerals, dietary fiber, and protein compared to other staple crops. Sweet potato also has cholesterol-lowering properties and can help prevent cardiovascular diseases.[9] It is also recognized as a valuable medicinal plant due to its ability to combat cancer, diabetes, and inflammation. Sweet potato is now recognized as an important source of natural products that have unique characteristics, some of which can be used in developing medicines for treating different diseases and in the production of industrial goods. A drug commonly used to treat diabetes.[12]

In addition to their nutritional value, sweet potatoes can be prepared in a variety of ways. They can be boiled, roasted, baked, mashed, or fried, and can be used in both sweet and savory dishes. Some popular sweet potato dishes include sweet potato pie, mashed sweet potatoes, and sweet potato fries. Sweet potatoes are also used in many cultural and traditional dishes, and are an important crop in many parts of the world. They can be stored for long periods of time and are a staple food in many regions.

Nutritional value of sweet potato powder :

Sweet potato powder is a popular ingredient in many types of baking and cooking. It is made by drying sweet potatoes (Ipomoea batatas) and then grinding them into a fine powder. The nutritional value of sweet potato powder is similar to that of fresh sweet potatoes, but the nutrient content can vary depending on the brand and how it is processed. According to a report, sweet potato has an overall antioxidant capacity of 42.94% when compared to ascorbic acid. Additionally, the purple-fleshed sweet potato has a greater antioxidant activity than the white-fleshed variety.[12]

According to the United States Department of Agriculture (USDA) National Nutrient Database, here are the approximate nutrient values for 100g of sweet potato flour:

Table 2 : Sweet Potato Flour

NUTRIENTS	VALUES PER 100g
Calories	368
Moisture	9.2 g
Ash	1.5 g
Protein	3.6 g
Fat	0.8 g
Carbohydrates	83.6 g
Fiber	10.3 g
Calcium	52 mg
Iron	1.9 mg
Magnesium	54 mg
Phosphorus	133 mg
Potassium	919 mg
Sodium	55 mg
Zinc	0.8 mg
Vitamin A	83012 IU
Vitamin C	2.4 mg
Vitamin E	1.81 mg
Vitamin K	1.8 µg
Thiamin	0.14 mg
Riboflavin	0.13 mg
Niacin	1.58 mg
Vitamin B6	0.35 mg
Folate	44 µg

Note : The nutritional composition of a food item can be influenced by several factors, including the quality and type of ingredients used, the processing method employed, and the conditions under which the food is stored. As a result, the nutritional value of a food may differ depending on these variables.

VIII. RESULTS

The study may have shown that the use of locally available cassava and sweet potato flour can help improve food security in regions where rice is a staple food but micronutrient deficiencies are prevalent and then fortifying rice with cassava and sweet potato flour significantly increases the amount of important micronutrients. The article may have highlighted the cost-effectiveness of fortifying rice with cassava and sweet potato flour as compared to other methods of addressing micronutrient deficiencies and and improve the overall health and well-being of people who consume it regularly.

Table 3 : Cassava and Sweet Potato Flour Mix

NUTRIENTS	VALUES PER 100g
Calories	349
Moisture	10.2 g
Ash	1.4 g
Protein	3 g
Fat	0.45 g
Carbohydrates	82 g
Fiber	4.7 g
Calcium	23 mg
Iron	1.34 mg
Magnesium	29 mg
Phosphorus	68 mg
Potassium	384 mg
Sodium	12 mg
Zinc	0.6 mg
Vitamin E	0.45 mg
Vitamin K	1.7 µg
Thiamin	0.07 mg
Riboflavin	0.069 mg
Niacin	1.13 mg
Vitamin B6	0.195 mg
Folate	25 µg

Note : The nutritional composition of a food item can be influenced by several factors, including the quality and type of ingredients used, the processing method employed, and the conditions under which the food is stored. As a result, the nutritional value of a food may differ depending on these variables.

IX. Conclusion

Fortified rice using cassava powder and sweet potato powder is a promising solution to the problem of malnutrition, especially in developing countries. By adding these powders to rice, it is possible to provide people with the nutrients they need to support their health and well-being. However, it is important to ensure that the powders are produced and stored in a way that maintains their nutritional value, and that the fortified rice is consumed regularly to achieve the desired health outcomes.

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