

**THE EFFECT OF THE QUICK SOAK TECHNIQUE AND STORAGE DURATION  
ON THE COOKING TIME AND WATER UPTAKE OF BIOFORTIFIED NARO  
BEAN VARIETIES**

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**UGANDA CHRISTIAN  
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## ABSTRACT

The common bean (*Phaseolus vulgaris L.*) is known to develop a hard-to-cook defect when stored for a long time. However, soaking the beans before cooking is a known method used worldwide to reduce the cooking time of beans. This study, therefore investigated the impact of storage time and the quick soak method on the cooking time of three iron bio-fortified NAROBAN varieties, NAROBAN 1, NAROBAN 3 and NAROBAN 6 stored for <1, 2 and 4 years.

Twenty-four beans of each of the 3 varieties stored for different times were weighed, boiled in distilled water for 3 minutes, and left to stand for 1 hour. Thereafter, the beans were cooked in the Mattson pin-drop cooker to determine the cooking time. After cooking, the beans were weighed to determine water uptake. Cooking time did not significantly vary with bean variety ( $p>0.05$ ) but with storage time ( $p<0.05$ ). The older beans took more time to cook. The quick soak technique significantly reduced cooking time ( $p<0.05$ ) especially for beans stored for a shorter time. These results provide a basis for recommendations to reduce the costs of fuel in cooking beans.

## DECLARATION

I, **TALWANA YVONNE GLORY**, hereby declare that this is my original work and has not been presented to any university or institution for an award of a degree, diploma or any other academic qualification.


STUDENT'S SIGNATURE:

A handwritten signature in black ink, appearing to be 'YVONNE GLORY', written over a horizontal line.

DATE: 8<sup>TH</sup> APRIL, 2025

## APPROVAL

This Dissertation has been organised by TALWANA YVONNE GLORY under my supervision and is now ready for submission to UGANDA CHRISTIAN UNIVERSITY for the award of BACHELOR OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY.

SIGNATURE:  .....

DATE: 07/04/2025

Dr. MARTIN MUTAMBUKA

## **DEDICATION**

To my parents Mr. Herbert and Mrs. Anne Talwana.

Your unwavering guidance and support has carried me through this journey. Your prayers have given me the strength to press on, and face challenges head on.

To my siblings Ernest, Yvette, Precious and Jonathan who have always cheered me on, those words of encouragement mean more than you could imagine. I am truly grateful.

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## LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA - Analysis of Variance

CIAT - International Centre for Tropical Agriculture

FAO - Food and Agricultural Organisation

HTC - Hard-to-cook

NABE - National Bean Varieties for Uganda

l -Litres

mg - milligrams

SD - Standard Deviation

% - percent

## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background of the study

The common bean (*Phaseolus vulgaris* L.) is an important legume in the world (Broughton et al., 2003) with an annual production of about 27.5 million metric tonnes on 34.8 million hectares (FAO, 2022). Common beans are an exceptional food resource because of their high protein content and combination of carbohydrates, dietary fibre, and minerals, particularly iron and zinc, in the pods and edible seeds (Heuzé et al., 2013). They are the most important source of income especially for women and youth (Akpo et al., 2020) and are arguably the cheapest nutrition source in Uganda, providing about 33% of dietary protein (Asiimwe et al., 2024; Aseete et al., 2018).

Given the importance of common beans in Uganda, high-yielding varieties such as NABE1, NABE2, NABE3, K131, and K132 have been developed and contribute to improving food security (Okii et al., 2014; Mukankusi et al., 2015). Research in Uganda has also developed the NAROBAN varieties including NAROBAN 1, 2, 3, 4, 5, 6 and 7 that are an excellent source of iron and zinc (Mukankusi et al., 2018).

The common bean is unpalatable in its raw state and must be cooked or processed before eating (Banti and Bajo, 2020). In Uganda, it is primarily consumed as dry grain, cooked without presoaking or the addition of a catalyst (Asiimwe et al., 2024). The cooking time ranges from 120 to 180 minutes, and many factors affect the cooking time of beans, such as genotype, storage time, and storage conditions (Aseete et al., 2018; Wang et al., 2016).

The Hard-to-Cook (HTC) defect is one of the key contributors to long cooking time of beans. It occurs mainly in legumes stored for a long period under conditions of high temperature (30- 40°C) and humidity (above 75%) leading to structural changes in the bean seed coat and cotyledon making them resistant to water absorption and heat breakdown, prolonging cooking time (Bressani & Chon, 1996).

One of the key mechanisms behind HTC is the pectin-cation-phytate interaction, where calcium ions cross-link with pectin, making the seed coat more rigid and resistant to heat penetration (Njoroge et al., 2016).

Some traditional methods such as soaking for long hours, cooking beans with catalysts (e.g., baking soda), and roasting have been explored to reduce cooking time (Nakitto et al., 2015). Soaking beans in salt solutions has also been found to counteract the Hard-to-cook defect. The salts increase protein solubility by replacing calcium ions, and enhancing pectin breakdown, leading to faster softening during cooking (Chigwedere et al., 2018).

A study by Didinger et al. (2023) highlights that the quick soak reduces the cooking time of dry pinto beans. This method involves boiling the beans for 3 minutes and then leaving them to sit for an hour in the hot water before discarding. Unlike the overnight soak, the quick soak method takes a shorter time which makes it more suitable for time-conscious consumers.

## **1.2 Problem Statement**

Since not all harvested beans can be consumed fresh, they are dried and stored to increase their shelf life. However, long storage time increases their susceptibility to developing the hard-to-cook defect. This defect contributes to longer cooking times and a harder texture (Parmer et al., 2017). Traditional bean cooking methods involve prolonged soaking and boiling and require much energy to soften the beans. The quick soak method has proved to reduce the cooking time of fresh pinto beans (Didinger et al., 2023), however, little research has been done to assess how it affects the cooking times of Ugandan beans after extended storage times. This study aimed at addressing whether the quick soak method could counteract the hard-to-cook defect exhibited by beans stored for extended periods.

### **1.3 Purpose and objectives**

The main objective of the study was to analyse the effectiveness of the quick soak technique in reducing cooking time of three NAROBAN varieties stored for extended periods (up to 4 years).

#### **1.3.1 Specific objectives**

1. To determine the cooking time of the three bean varieties stored for different periods after quick soak processing.
2. To determine the water uptake of the cooked bean varieties across the storage durations and soaking treatments.

#### **1.3.2 Hypotheses**

1. There is no difference in the cooking time of the NAROBAN varieties across different storage periods.
2. There is no difference in the water uptake of the NAROBAN varieties across the different storage durations and soaking treatments.

### **1.4 Scope of the Study**

The study focuses on the cooking time of three iron bio-fortified bean varieties stored for three time periods.

The study focused on the cooking time of three iron bio-fortified bean varieties stored for three time periods. These beans were sampled from the Alliance Bioversity Gene Bank in Kawanda where they were stored at controlled conditions. The seeds were subjected to quick soak method. The main goal was to understand how these three factors affect the cooking time. The research was conducted in a laboratory setting at the Alliance Bioversity International - CIAT laboratory, located in NARO Kawanda Agricultural Research Institute, Kampala with the use of standardized methods of soaking, cooking and measurement of water uptake.

## **1.5 Justification**

The consumption of NAROBAN varieties has increased since they were first introduced to Ugandan markets in 2016. However, extended storage times of the dry beans leads to the development of a hard-to-cook defect which increases their cooking time.

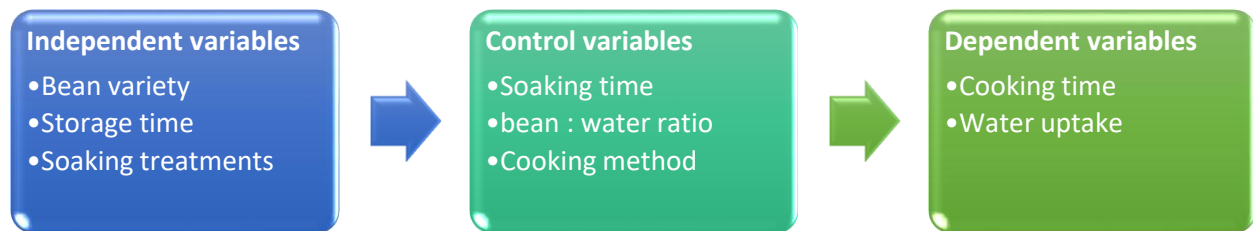
Given the rising cost of fuel and the need for energy-efficient cooking, finding practical solutions to reduce cooking time is critical. The quick soak method provides a faster alternative to prolonged soaking hours that could also mitigate the hard-to-cook defect.

This research provided evidence-based recommendations for Ugandan households and policymakers to improve bean cooking efficiency, reduce fuel costs, and enhance food security using locally available materials.

## **1.6 Significance of the Study**

The importance of common beans as a source of proteins, carbohydrates, dietary fibre, and microelements, particularly iron and zinc, is well documented. However, long cooking times (120-180 minutes) are reported for dry beans, depending on the variety. Cooking methods and factors like the HTC defect can limit the consumption of common beans. This study will provide information on the use of the quick soak method to reduce the cooking time of three bio-fortified bean varieties in Uganda. The findings from this study are valuable in providing evidence-based recommendations to Ugandan households and policymakers on practical and cost-effective ways to improve bean cooking efficiency, reduce fuel costs, and enhance food security using locally available materials.

## 1.7 Conceptual Framework



The conceptual framework illustrates the key variables and their relationships in this research. The independent variables are the bean variety, storage time and soaking treatments, which are expected to influence the cooking time of the beans.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Importance of beans in Ugandan households

Globally, a wide range of grain legumes are vital for food security and agricultural sustainability. Among the most grown are common beans (*Phaseolus vulgaris*), Cowpeas (*Vigna unguiculata*), pigeon peas (*Cajanus cajan*), groundnuts (*Arachis hypogaea*), soybeans (*Glycine max*), field peas (*Pisum sativum*), chickpeas (*Cicer arietinum*), bambara groundnuts (*Vigna subterranea*), lentils (*Lens culinaris*), mung beans (*Vigna radiata*), black gram (*Vigna mungo*), faba beans (*Vicia faba*), lablab beans (*Lablab purpureus*), tepary beans (*Phaseolus acutifolius*), African yam beans (*Sphenostylis stenocarpa*), Kersting's groundnut (*Macrotyloma geocarpum*), each adapted to specific agroecological niches (Kloh Fukah et al., 2024). Among these, the common bean (*Phaseolus vulgaris* L.) is the most important legume for consumption by billions of populations in the world. The global average bean consumption per capita is about 2.58 kg (FAOSTAT, 2022). The six highest producers of beans include Brazil, India, Mexico, the United States of America, Tanzania, and Uganda respectively (FAOSTAT, 2022).

In Uganda, the common bean (*Phaseolus vulgaris* L.) is also the most important legume crop grown and consumed. Approximately, 1,060,000 hectares of land is planted annually, which represents about 12.14% of cultivated area, making Uganda to be among the leading five producers of common beans in Africa and the second East African producer after Tanzania (FAOSTAT 2022; Kilimo Trust, 2012). Uganda produces about 425,400 tons of dry beans annually (FAOSTAT, 2022), and most Ugandan farming households grow beans twice a year. The crop is produced mainly by smallholders for food and the excess is sold to acquire other needs. Beans are also among the important non-traditional exports for Uganda which signifies the importance of the crop in rural and urban areas especially among smallholder farmers (UBOS 2020). Per capita bean consumption is about 9.8kg annually, contributing, on average, 12% of total protein and about 4% of total calorie intake consumed per person (FAOSTAT, 2022). It is applauded in Uganda as a strategic remedy for hidden hunger and healthy eating and is mostly

important for children and women of reproductive age (de Jager, 2013). It is an excellent source of cholesterol-free dietary proteins, energy, fibre, micronutrients (Ca, Fe, Cu, Zn, P, K, and Mg) and vitamins A, C, KB6, and folic acid. (Azarpazhooh and Boye, 2012; Kotue et al., 2018; Carbas et al., 2020). Beans contribute significantly to nutrition and food security, income and employment of most households in Uganda (Larochelle et al., 2015). Per capita bean consumption in Uganda is about 10 kg annually, contributing about 12% of total protein and 4% of total calorie intake (FAOSTAT, 2022) and over 80% of Ugandan households can consume beans over the 7-day period, in both rural and urban areas (Larochelle et al., 2016).

## **2.2 Limitations to Bean Consumption**

Whereas it is globally acceptable that beans are nutritious, affordable, versatile and delicious, as well as good for environmental health, global bean consumption is low, with levels stagnating at around 21 grams per day (FAOSTAT, 2022), notwithstanding that in developing countries, for example, Kenya, Rwanda and Burundi, bean consumption is significantly higher; estimated to 80 g per day per capita (FAOSTAT, 2022). Emerging consumer trends and preferences toward healthy foods, plant protein alternatives, and environmental concerns can enhance the consumption of legume-based foods (Affrifah et al., 2023). However, several limitations to bean consumption have been identified in literature including a lack of familiarity of how to cook and prepare beans, concerns about flatulence and other anti-nutritional factors, dislike of the taste and or texture, a negative stigma of pulses as a poor person's food or only for vegetarians, and long cooking times (Didinger et al., 2023).

### **2.2.1 Anti-nutritional factors in common beans**

Common beans contain a variety of anti-nutritional factors, such as phytic acid, tannins and lectins that negatively impact nutrient absorption in the body. Phytic acid hinders the absorption of nutrients like calcium, magnesium, iron and zinc. It binds to these nutrients forming insoluble complexes that cannot be absorbed thus reducing their bioavailability (Wiesinger et al., 2019; Petry et al., 2012). Tannins interfere with the body's ability to absorb iron and proteins (Guiberti et al., 2019). They bind with proteins

forming complexes that are difficult to absorb. Tannins may also irritate the digestive system, hindering its ability to digest food.

Anti-nutritional factors in legumes, such as phytic acid, trypsin inhibitors, saponins, vicin and convicin, lectins, and condensed tannins, can be eliminated or destroyed using various processing techniques such as soaking, heat processing (boiling, autoclaving and extrusion), sprouting and fermenting (Campos-Vega et al., 2018; Banti and Bajo, 2020; Das et al., 2022).

### **2.2.2 Iron Bioavailability and Bio-fortification**

Phytic acid is an anti-nutrient that inhibits the bioavailability of iron in beans. Recently, research has focused on increasing iron bioavailability rather than its concentration in beans since some bean varieties provide more bioavailable iron regardless of concentration (Petry et al., 2013). In Uganda, trials conducted have shown significant environmental and genotype effects on iron concentration, complicating the sustainability of high iron varieties (Glahn et al., 2020). Regions like Eastern Africa and Latin America which consume common beans as a staple food have made efforts to fortify their beans to enhance the bioavailability and concentration of iron.

To keep pace with growing consumer demands, breeders have adopted strategies that effectively improved iron bioavailability in common beans. Currently, 45 new bio-fortified bean packed with high iron and zinc have been developed and made available to more than 10 million people across several countries including Angola, Burundi, Cameroon, Democratic Republic of the Congo, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Rwanda, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe, Sierra Leone, South Sudan, Togo, etc. (Sperling et al., 2013).

### **2.3 Bean cooking time**

Cooking beans is a thermal transformation process which makes the nutrients and micronutrients contained in bean seeds available to the human body. Cooking is fundamental for bean preparation and consumption, as it increases digestibility,

inactivates anti-nutritional factors, increases nutrient biological value and provides the sensorial quality and colour characteristics requisite with consumer demands (Aseete et al., 2018; Asiimwe et al., 2024).

There is a wide variability in cooking times of common beans, ranging from less than 45 minutes (short cooking time) to more than 60 minutes (long cooking time), and they can take up to 3 hours to cook (Muyonga, et al., 2008). In most developing countries, short cooking time is emerging as a consumer-preferred trait (Beebe et al., 2013), and most subsistence farmers highly regard taste and cooking time as preference traits in common beans (Katungi et al., 2014).

### **2.3.1 Factors influencing cooking time**

The cooking times of dry beans are dependent on many factors including growing conditions, post-harvest handling and storage (storage time, humidity and temperature of storage environment), cooking methods, and genotype (seed size, grain thickness and flatness) (Wiesinger et al., 2019).

Poor storage conditions increase bean cooking times; for example, if beans are dried and stored with less than 10% seed moisture content, the beans tend to take longer to cook than freshly harvested beans (Reyes-Moreno et al., 2000). The beans stored in such dry state may develop a defect called ‘hard shell’, and such seeds do not take up any water as a result of the closure of all possible entrance points for water. It is thought that the ‘hard shell’ phenomena slows the rate of water uptake, cell separation, starch gelatinization, and protein hydrolysis, all of which are traits that have been associated with differences in the cooking times of dry beans (Njoroge et al., 2015). Storage conditions fluctuation especially of temperatures to above 25°C and relative humidity to higher than 65% increase bean susceptibility to developing hard-to-cook defects (Coelho et al., 2007).

Cooking time varies across bean genotypes (Katuraamu et al., 2020) and some of the genotype characters considered to be related to bean cooking time are differences in seed appearance in terms of colour, pattern, and shape; the seed coat, which serves

as a physical barrier to water uptake; the micropyle, hilum, strophiole, and raphe that are the primary means of water entry into the bean; the seed coat thickness as well as the thickness of individual seed coat layers; and the cotyledon and cotyledon cell wall made up of cellulose, hemicellulose, pectin, neutral sugars, proteins, glycoproteins, lignin, and phenolic compounds that reduce water absorption (Cichy et al., 2019).

Prolonged storage of beans in severe conditions results in beans requiring longer cooking times since they have high resistance to softening during cooking, a phenomenon called “hard-to-cook” (HTC) [Maurer et al., 2004]. Prolonged cooking of beans due to the HTC defect has been reported to increase the percentage of leached solids, to destroy heat-labile vitamins and to decrease the protein quality of the cooked product (Perera et al., 2023). The hard-to-cook defect is a serious issue affecting the softening of beans even after cooking. It is characterised by prolonged cooking times and tough texture of the seeds. This phenomenon is brought about by the pectin-cation-phytate interaction, where calcium ions cross-link with pectin, making the seed coat more rigid and resistant to heat penetration over time (Njoroge et al., 2016). The HTC defect is influenced by factors like storage conditions paired with anti-nutritional factors. This complicates the preparation and consumption of common beans (Pirhayati et al., 2011).

At the household level, the hard-to-cook (HTC) defect limits bean consumption, as it leads to prolonged cooking times (Sgarbieri and Whitaker, 1982; Reyes-Moreno et al., 1993). In Uganda, beans are typically cooked without prior processing, using wood fuel or charcoal, which can take 2 to 3 hours (Aseete et al., 2018; Kinyanjui et al., 2014). This constrains the consumption demand for beans, as it is neither convenient nor affordable to prepare them frequently.

### **2.3.2 Reducing cooking time of beans**

Due to the economic and social importance of dry beans, the time it takes to cook them affects the consumption habits and nutritional status of large populations of the world. Cooking fuel may be cost-prohibitive to some bean consumers, notably the poor urban

demographic in East Africa who rely on charcoal for cooking (Asiimwe et al., 2024). Hence, many consumers in developing countries prefer beans with shorter cooking times (Asiimwe et al., 2024; Kilima and Bolle, 2020; Zapata, 2019).

Reducing cooking time could increase dry beans (*Phaseolus vulgaris*) consumption. Cooking is an essential processing step needed to unlock the nutrients in dry beans and to make them palatable and safe for consumption. Long cooking times have consequences for dry bean use, especially where cooking fuel cost is high and when people prefer foods that are more convenient to prepare.

Many processing methods have been identified to reduce the hard-to-cook defect. Traditional processing techniques, such as soaking, dehulling, milling, boiling/cooking, roasting, pounding, and germination, can alter the composition and functionality of beans, reducing preparation time and fuel requirements (Annor et al., 2014). Soaking is the most widely applied pre-processing method to soften beans and reduce cooking time (Bellido et al., 2006). Emerging studies have shown that soaking in solutions like NaCl and NaHCO<sub>3</sub> can effectively counteract the HTC defect and significantly reduce the cooking time of beans (Didinger et al., 2023; Chigwedere et al., 2018). Soaking and utilizing hydrothermal treatments can effectively soften bean seeds during cooking (Satya et al., 2010). Moreover, the incorporation of certain additives during soaking can significantly enhance the cooking quality of beans, demonstrating a practical approach to address the HTC defect (Huma et al., 2008; Yahaya et al., 2022).

There are three major soaking methods: the hot-dip, traditional and quick soak. The traditional soak (long soak) is the most common method used to soak of beans. Here, the beans are submerged completely in water and left soaking for 8 hours or overnight before cooking, in which case the complex sugars can be reduced by up to 60%. The hot-dip soak is the suggested method that reduces gas-producing compounds and cooking time, but it is long term process. The beans are placed in a large pot and then 10 cups of water are added for every 2 cups of beans. The soaked beans are heated to boiling and left boiling for 2 to 3 minutes. They are removed from the heat and left to stand for 4 to 24 hours while covered. The quick soak method is short term process

that can reduce 80% of complex bean sugars. For this method, beans are placed in a large pot and 6 cups of water for every 2 cups of beans are added. The beans are then brought to boil and kept boiling for an additional 2 to 3 minutes. The pot is removed from heat, and left standing while covered for 1 hour.

## CHAPTER THREE

### 3.0 METHODOLOGY

#### 3.1 Sourcing of materials

Three iron bio-fortified bean varieties; NAROBEAN 1,3 and 6 stored for <1 year, 2 years and 4 years (harvested in 2024, 2022 and 2020 respectively) were sourced from the Alliance Bioversity - CIAT gene bank. The beans were sorted, cleaned and their moisture content was measured using a calibrated Sinar 6095 AgriPro handheld moisture meter.

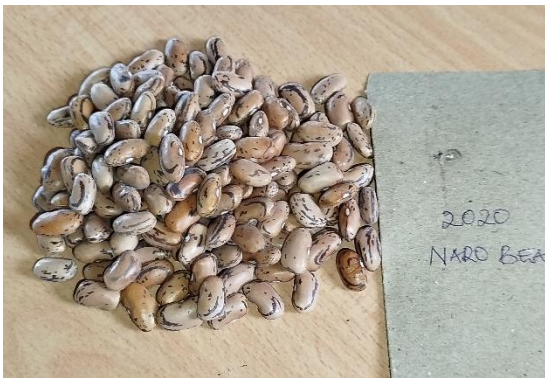


Figure 1: Sample of NAROBEAN 1



Figure 2: Sample of NAROBEAN 3



Figure 3: Sample of NAROBEAN 6



Figure 4: Loading beans into the moisture meter

### **3.2 Sampling**

Seeds were sampled in three groups per variety according to their age. They were further divided into two groups for the two soaking treatments. Subsampling was done by removing 24 beans of uniform size, shape and colour. The samples were weighed and packed in labelled envelopes.

### **3.3 Soaking Treatments**

Two soaking treatments were applied; the no soak where beans were boiled directly without soaking and quick soak where the beans were boiled for 3 minutes in distilled water, and left to stand for 1 hour before cooking. After soaking, the soaking water was drained and the beans were put in blotting paper to remove excess surface water. The soaked seeds were weighed and stored in glass bottles before cooking.

### **3.4 Cooking Time Measurement**

Cooking time was measured using the Mattson pin-drop cooker method, which records the time taken for the beans to be fully softened (Wang and Duan, 2005).

The Mattson cooker machine consisting of a plate with 25 wells was used to perform the cooking time analysis. 24 beans from each soaking treatment were placed in the wells of the Mattson cooker, with 90g weighted stainless steel rods and a 2mm pin resting on each bean. A temperature monitor was placed in the 25<sup>th</sup> well to monitor the temperature during the experiment.

The machine was lowered into a beaker with 2.5l of boiling distilled water. The machine was activated using a web application.

The time required for the pins to fully pierce the beans was recorded as the cooking time. Each soaking method was tested in triplicate to ensure statistical accuracy.



Figure 5: Weighted rods resting on beans



Figure 6: Mattson cooker set up



Figure 5: Removing cooked beans from the Mattson cooker

### 3.5 Water uptake

After cooking, the beans were removed from the pins and placed between sheets of blotting paper to remove the surface water. The samples were weighed and their weight was recorded.

Water uptake was calculated using by subtracting the dry weight ( $W_1$ ) of the beans from the cooked weight ( $W_2$ ) then dividing by the dry weight (Deshpande and Cheryan,1986). This was expressed in percentage.

$$\text{Percentage water uptake} = \frac{\text{Cooked weight}(W_2) - \text{Dryweight}(W_1)}{\text{Dry weight}(W_1)} \times 100$$

### **3.6 Experimental Design**

The experiment followed a  $3 \times 3 \times 2$  factorial design with three factors; bean variety at 3 levels, storage time at three levels and treatment at 2 levels combined together to create 18 experimental units.

The experiment was conducted in triplicate for statistical accuracy.

### **3.7 Data Analysis**

Analysis of Variance was conducted on 54 samples to determine the effect of bean variety, storage time and soaking treatments on the cooking time and water uptake of the beans. Scheffe's post-hoc test was used to determine the significant differences between groups ( $p < 0.05$ ).

## CHAPTER FOUR

### 4.0 RESULTS AND DISCUSSION

#### 4.1 Bean cooking times

Table 4.1 shows the interaction between the three independent variables (bean variety, storage time and soaking treatment) on cooking time. The overall model was significant ( $p < 0.05$ ) indicating that at least one independent variable or interaction significantly affected the cooking time. There were significant interactions between bean variety and soaking treatment. All the other interactions were not significant.

The main effects of bean variety ( $p = 0.0048$ ) and storage time ( $p = 0.0003$ ) were also significant. The main effects of soaking treatment were not significant.

Table 4.1: Analysis of Variance Table for Cooking Time

Source of variation	p-value
Model	0.0016
Bean variety	0.0048*
Storage time	0.0003*
Bean variety × Storage time	0.3487
Treatment	0.3226
Bean variety × Treatment	0.0224*
Storage time × Treatment	0.0893
Bean variety × Storage time × Treatment	0.5097

\* indicates statistical significance at  $p < 0.05$

Table 4.2 shows the cooking times of the different bean varieties. There were significant differences in cooking times of the bean varieties with NAROBAN 6 having the longest cooking time (121.88 minutes) while NAROBAN 3 had the shortest (91.42 minutes). There were significant differences in cooking times between NAROBAN 6 and NAROBAN 3. There was no significant difference between the cooking time of NAROBAN 1 and NAROBAN 3, and NAROBAN 1 and 6.

Table 4.2: Cooking time of the three bean varieties.

Bean variety	Cooking time (mins)
NAROBAN 1	96.16 ± 30.87 <sup>ab</sup>
NAROBAN 3	91.42 ± 21.66 <sup>a</sup>
NAROBAN 6	121.88 ± 47.42 <sup>b</sup>

Results are shown as mean ± SD. Means with the same superscripts down the column are not significantly different at  $p > 0.05$ .

Table 4.3 shows the cooking times of beans at different storage durations. There were significant differences in cooking times across the storage durations. Cooking time increased with an increase in storage time. There was a significant difference in the cooking time of beans stored for 4 years and <1 year. There was no significant difference in the cooking time of beans stored for 2 years and the rest of the bean storage times. Refer to Appendix A for the ANOVA table.

Table 4.3: *Cooking times of beans stored for different periods*

Storage duration	Cooking time (mins)
4 years	121.95 ± 40.02 <sup>a</sup>
2 years	106.53 ± 37.40 <sup>ab</sup>
< 1 year	80.98 ± 18.23 <sup>b</sup>

Results are shown as means ± SD. Means with the same superscripts down the column are not significantly different at  $p > 0.05$ .

#### 4.1 Water uptake

Table 4.4 shows the ANOVA results of the interaction between bean varieties, soaking treatments and bean storage times with respect to water uptake. There were no significant interactive effects. Only the main effects of bean variety were significant ( $p = 0.0137$ ). This suggests that the water uptake varied significantly across the three bean varieties.

There were no other significant main effects observed for the storage time of the beans and the treatments used. None of the interactions were significant for water uptake.

Table 4.4: Analysis of Variance for Table for Water Uptake

Source of variation	p-value
Model	0.0866
Bean variety	0.0137*
Storage time	0.1918
Bean variety × Storage time	0.1416
Treatment	0.1635
Bean variety × Treatment	0.6486
Storage time × Treatment	0.3048
Bean variety × Storage time × Treatment	0.7044

\* indicates statistical significance at  $p < 0.05$

Table 4.5 shows the water uptake by the different bean varieties. There were significant differences in water uptake across the bean varieties. NAROBAN 1 had the highest water uptake while NAROBAN 6 had the lowest. There was a significant difference in the water uptake between NAROBAN 1 and NAROBAN 6. However, there was no significant difference between NAROBAN 3 and both NAROBAN 1 and 6. Refer to Appendix A for the ANOVA table.

Table 4.5: Table showing water uptake by the different bean varieties

Bean variety	Water uptake
NAROBAN 1	129.83 ± 24.01 <sup>a</sup>
NAROBAN 3	114.06 ± 29.21 <sup>ab</sup>
NAROBAN 6	103.38 ± 23.15 <sup>b</sup>

Results are shown as means ± SD. Means with the same superscripts down the column are not significantly different at  $p > 0.05$

## **4.2 Discussion of the results**

The main objective of this study was to determine the effect of the quick soak technique on the cooking time of NAROBAN varieties stored for different periods. The findings provide information for improving cooking efficiency which is necessary for reducing fuel costs during preparation.

### **4.2.1 Cooking time**

The study showed that storage duration significantly affected the cooking time of bio-fortified NAROBAN varieties with the older beans requiring more time to cook, aligning with previous research on the Hard-to-cook defect which develops in legumes stored for extended periods (Bressani & Chon, 1996).

HTC defect is as a result of the structural changes in the seed coat and cotyledon, such as the pectin-cation-phytate interactions which increase rigidity and resistance to heat penetration (Njoroge et al., 2016). These changes explain why the beans stored for four years took longer to cook compared to those stored for two years and less than a year.

The quick soak reduced the cooking time of all three bean varieties across the storage durations, particularly for beans stored for less than one year. This result is in line with the study by Didinger et al. (2023), which found that the quick soak technique successfully reduces cooking time by softening the bean structure and enhancing water absorption. The mechanism involves partial gelatinization of starch and breakdown of pectin in the seed during the initial boiling phase, facilitating faster heat transfer during subsequent cooking (Chigwedere et al., 2018).

### **4.2.2 Water uptake**

NAROBAN 6 had a lower water uptake than NAROBAN 3 and 1. This could be attributed to the differences in the genotype, seed size and shape evidenced by Katuraamu et al., (2020). The study also found that water uptake was influenced by both storage duration and the soaking treatment used. Beans stored for longer periods exhibited lower water uptake, which can be attributed to structural changes caused by the hard-to-cook defect that reduce permeability and hinder water absorption

(Parmer et al., 2017). The findings relate to previous studies indicating that prolonged storage under unfavourable conditions leads to hardening of cell walls, making beans less responsive to hydration during cooking.

The quick soak method improved water uptake across all storage durations, which shows how effective it is in lowering the effects . This finding is consistent with Chigwedere et al. (2018), who reported that soaking treatments enhance protein solubility and breakdown pectin structures, thereby improving water absorption during cooking. The increase in water uptake not only contributes to faster softening but also enhances the texture and palatability of cooked beans.

## CHAPTER FIVE

### 5.0 CONCLUSION AND RECOMMENDATIONS

#### 5.1 Conclusion.

The results showed significant variation in cooking times among the NAROBAN varieties across storage time groups. The beans that were stored for four years showed the longest cooking times, followed by those stored for two years, then beans stored for less than a year. Therefore, the null hypothesis that states; there is no difference in the cooking time of the NAROBAN varieties across different storage periods was rejected.

The statistical analysis also showed that the quick soak technique did not significantly influence the cooking time of the beans. However, there was a significant interaction between the bean variety and soaking treatments.

Bean variety had a significant effect on the water uptake with NAROBAN 1 and 3 showing a higher percentage water uptake than NAROBAN 6. Therefore, the null hypothesis that states there is no difference in the water uptake of the NAROBAN varieties across the different storage durations and soaking treatments was rejected.

#### 5.2 Recommendations.

Utilization of these research findings in the processing industry to inform manufacturers' choice of NAROBAN variety to use for value addition.

Further research on soaking treatments with varied soaking times and concentration of salt solutions to explore their effects on hard-to-cook beans.

Optimization of bean cooking techniques using the quick soak and development of practical cooking guidelines for Ugandan households to increase cooking efficiency and reduce fuel costs.

Further studies to determine the effect of soaking treatments, particularly the quick soak on the nutrient retention of NAROBAN varieties.

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## APPENDICES

### APPENDIX A: ANOVA tables

#### ANOVA Results for Cooking Time

```
. anova meancookingtime beanvariety1##storageduration##treatment1
```

```
Number of obs =      54    R-squared      =  0.6017
Root MSE      =  28.2388    Adj R-squared =  0.4136
```

Source	Partial SS	df	MS	F	Prob>F
Model	43360.404	17	2550.612	3.20	0.0016
beanvarie~1	9933.7584	2	4966.8792	6.23	0.0048
storagedu~n	15975.409	2	7987.7043	10.02	0.0003
beanvarie~1#storagedu~n	3669.9129	4	917.47823	1.15	0.3487
treatment1	802.01196	1	802.01196	1.01	0.3226
beanvarie~1#treatment1	6749.0788	2	3374.5394	4.23	0.0224
storagedu~n#treatment1	4123.631	2	2061.8155	2.59	0.0893
beanvarie~1#storagedu~n#treatment1	2675.5699	4	668.89248	0.84	0.5097
Residual	28707.561	36	797.43226		
Total	72067.966	53	1359.7729		

#### ANOVA Results for Water Uptake

```
. anova agewaterabsorption beanvariety1##storageduration##treatment1
```

```
Number of obs =      54    R-squared      =  0.4468
Root MSE      =  24.7287    Adj R-squared =  0.1856
```

Source	Partial SS	df	MS	F	Prob>F
Model	17783.366	17	1046.0803	1.71	0.0866
beanvarie~1	5930.1313	2	2965.0657	4.85	0.0137
storagedu~n	2115.1279	2	1057.5639	1.73	0.1918
beanvarie~1#storagedu~n	4512.231	4	1128.0577	1.84	0.1416
treatment1	1237.32	1	1237.32	2.02	0.1635
beanvarie~1#treatment1	535.84274	2	267.92137	0.44	0.6486
storagedu~n#treatment1	1501.8866	2	750.9433	1.23	0.3048
beanvarie~1#storagedu~n#treatment1	1330.9295	4	332.73238	0.54	0.7044
Residual	22014.286	36	611.50794		
Total	39797.652	53	750.89909		

## ANOVA Results for Effect of Bean Variety on Cooking Time

. oneway meancookingtime beanvariety1, scheffe

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	9668.11005	2	4834.05502	3.95	0.0254
Within groups	62399.8557	51	1223.52658		
Total	72067.9658	53	1359.77294		

Bartlett's test for equal variances:  $\chi^2(2) = 9.9378$  Prob> $\chi^2 = 0.007$

Comparison of Mean cooking time by Bean Variety1  
(Scheffe)

Row Mean- Col Mean	1	3
3	-4.73278 0.921	
6	25.7206 0.098	30.4533 0.041

## ANOVA Results for Effect of Storage Duration on Cooking Time

. oneway meancookingtime storageduration, scheffe

Source	Analysis of Variance			F	Prob > F
	SS	df	MS		
Between groups	15413.4269	2	7706.71343	6.94	0.0022
Within groups	56654.5389	51	1110.87331		
Total	72067.9658	53	1359.77294		

Bartlett's test for equal variances:  $\chi^2(2) = 10.1137$  Prob> $\chi^2 = 0.006$

Comparison of Mean cooking time by Storage duration  
(Scheffe)

Row Mean- Col Mean	2020	2022
2022	-15.4233 0.388	
2024	-40.9689 0.002	-25.5456 0.081

