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# Nutrition and Quality Assessment for Horticultural Crops Grown in Different Locations and Conditions in Rwanda

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***Abstract*—** *Herein, we investigated the nutritional value and quality assessment for horticultural crops grown in different locations and conditions in of Rwanda. Different fruits and vegetables such as tomatoes, carrots, irish potatoes, bell peppers grown in screen houses and open field/markets were used in this study. The findings of this study have shown that screen house tomatoes have more carbohydrates and fibers, indicating better nutritional quality compared to the ones from the market. Additionally, screen house tomatoes and carrots contain higher levels of vitamin C and carotenoids, which are valuable antioxidants contributing to their nutritional quality as well. Moreover, bell peppers from the screen house may offer better nutritional quality and more consistent quality compared to bell pepper products from the market. Bell peppers exhibited also lower pesticide residues, as alpha-cypermethrin, cypermethrin, and dethane were not detected in the samples. This denotes that the quality of analyzed samples may not cause any harmful effect to the consumers. Therefore, the use of screen houses and other measures to control environmental impact on horticultural commodities are highly recommended in order to produce high quality horticultural crops.*

***Keywords*—** *Horticultural crops, quality, nutrition, screen houses, pesticide residues.*

## I. Introduction

Horticultural production in Rwanda is highly distributed in all 30 districts. In Rwanda, the four main types of horticultural produce are fruits, vegetables, nuts, and flowers. Numerous fruits and vegetables are linked to good health outcomes and can help to alleviate micronutrient shortages (O'Beirne et al., 2014). The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) recommend that individuals consume 400 g day-1 of vegetables and fruits to prevent chronic diseases (HWO, 2004). The consumption of fresh products, on the other hand, has been associated with a higher intake of some chemicals from applied pesticides such as alpha cypermethrin, cypermethrin, dethane, etc. in addition to environmental pollutants (Gruszecka-Kosowska & Baran, 2017).

Horticultural crops such as fruits, vegetables, nuts, herbs, and ornamental plants, play a crucial role in the global agricultural market due to the extensive applications and nutritional significance that they present. In addition, the quality of these fruits and vegetables has been mstly determined based on thier visible attributes such as size, shape, and color (Ariesen-Verschuur et al., 2022). On the other hand, because of an increase in consumer awareness, a shift towards more intrinsic qualities has been realized, showing the importance of organoleptic characteristics such as flavor, texture, aroma, and health-enhancing components, including vitamins, minerals, and antioxidants (Mullins and Wolt, 2022; Petrescu et al., 2020; Souza et al., 2023). These characteristics are frequently the basis of evaluation for consumers and can significantly influence the purchasing decisions (Petrescu et al., 2020). For example, a red tomato is generally considered fresh and ripe; however, a dull or oddly shaped tomato may not be acceptable. Horticultural crops' internal quality attributes include things like taste, texture, scent, and nutritional value.

The presence of pesticide residues in horticultural produces (fruits and vegetables) has significant implications in the rational development and appropriate utilization of pesticides, protecting the environment and human health, and reducing unnecessary loss of agriculture and international trade disputes. Nowadays, food safety and environmental protection concerns have attracted global attention. Many countries in the world attach great importance to the issue of pesticide residues and have imposed limits on pesticide residues on horticultural products (Y.-F. Li et al. 2014).

In the present study, data were collected with the objective of comparing their quality as they are from different locations, and also with different farming methods based on seed type and farming methods. These samples were taken to the lab to be analyzed. Samples of irish potatoes were taken from two districts (Musanze and Nyabihu). On the other hand, samples were collected from different sources, including aeroponic and conventional cultivation methods, as well as from the market in Musanze. Samples for vegetables were taken from two districts (Kicukiro and Kamonyi) where samples were taken from screen houses and market places. The main objective was to evaluate



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the quality characteristics of these products based on where the samples were taken from.

## II. MATERIALS AND METHODS

All determinations were performed using validated methods.

### 2.1. Determination of Dry Matter Content

The sample was placed in a porcelain capsule, brought to a constant mass, and weighed 15 g using an analytical balance with an accuracy of 4 decimals. The sample was then placed in a Venti-Line oven and heated to T = 105 °C for 4 hours in order to measure the dry matter content. The capsules were dried, chilled in a desiccator, and then recanted. The formula was used to calculate the dry matter:

$$D.M (\%) = (m\ dry/m\ wet) \times 100,$$

Where:
m dry = mass of the sample after drying (g) and
m wet = mass of the sample before drying (g).

### 2.2. Determination of Ascorbic Acid

Ascorbic acid was determined by titration where an aliquot of 20 mL was introduced into a 250 mL conical flask then diluted to about 150 mL and 1 mL of starch indicator solution is added then titration done with 0.005 mol L−1 iodine solution. The first permanent trace of a dark blue-black color caused by the starch-iodine complex is found to be the titration's endpoint. The liquid extracts of samples were titrated by calibrated titrant. After titrations, results were expressed as mean ± confidence limits at 95% confidence level. Then, the amount of AA (mg) was calculated in mg/100g.

The content of vitamin C was calculated according to the equation:

Vitamin C (mg 100 $g^{-1}$) = V titre*0.044*Vtotal*100/Va*Weigh

### 2.3. Determination of Carotenoids

A 10 g sample was extracted with 10 mL of 1/1/1 (v/v/v) methanol/ethyl acetate/petroleum solvent mixture, followed by vortex agitation for 1 min, sonication for 15 min, and centrifugation at 8000 rpm for 10 min in a centrifuge. Four washes performed with a saturated NaCl solution and the separation of the organic phase will be performed in the separating funnel. The organic phase will be initially filtered off with anhydrous $Na_2SO_4$. The filter was washed with petroleum ether until complete discoloration.

The absorbance spectrum of each supernatant was measured and the absorption maxima were read at 453, 505, 645 and 663 nm (UV/VIS spectrophotometer Cary 50 Scan). Chl a, Chl b, β-carotene and lycopene content was calculated from the following equations:

Chlorophyll a (mg/100) = 0.999A 663 -0.0989A 645
Chlorophyll b (mg/100) = 0.328A 663 +1.77A 645
Lycopene (mg/100ml) = 0.0485A 663 +0.204A 645 +0.372A 505 -0.0806A 453
Beta Carotene(mg/100ml) =0.216A 663 -1.22A 645 -0.304A 505 +0.452A 453

### 2.4. Pesticide residues

Approximately 1kg of tomato samples were homogenized with a blender for 1 min at room temperature. Then in a centrifuge tube, 10 g of previously homogenized sample were weighed, 15 ml of solvent were poured into it and then it was manually shaken by one minute. Thereafter, 6 g of anhydrous $MgSO_4$ and 1 g of sodium acetate were added, and it was shaken again. The tube was centrifuged at 4500 rpm for 5 min and 10 ml of the supernatant (solution A) were measured using a pipette and then transferred to a 15 ml centrifuge tube. In the case of the clean-up procedure, 2.5 mg of PSA (primary/ secondary amine) and 150 mg of anhydrous $MgSO_4$ were added for each extract milliliter (1 ml) of solution A. It then underwent a 30-second shaking and a 2-minute centrifugation at 4500 rpm. Finally, the supernatant was filtered through a 0.22 μm PTFE filter. This supernatant is the one to be read in HPLC for pesticide determination.

### 2.5. Determination of starch

The residue obtained after extraction of solid sugars was mixed with a little distilled water, then heat moderately at a constant temperature on sand bath to obtain a kind of starch paste. After cooling, perchloric acid 52% is added and react for 12 hours, then stilled adding 5ml of perchloric acid 52% and transferred in the balloons of 100ml. Of this solution, pipette 1ml and put it in a tube of centrifugation and add 2ml of Zinc sulfate 2% and 2ml of barium hydroxide 1.8%. Centrifugation is then done for15 minutes at 3000 rpm per minute. The supernatant is put in test tubes, then phenol and sulfuric acid are added before reading in spectrophotometer at 490nm.

Calculations are done as per the following formula
% of Starch = Weight of dextrose + weight of CO2
= [AbscxFCx7x5x100x10-6 + (nber moles dextrose – 1) x 44] x 100

### 2.6. Dry matter

The determination of dry matter was performed as per the above method of oven-drying.

## III. RESULTS AND DISCUSSIONS

### 3.1. Moisture and starch content

The provided statistics offer insights into the moisture content of Irish potatoes across various seed types and farming methods. The data reveals notable differences among these categories. For example, Mini-Kinigi (Aeroponic) stands out with the highest mean moisture content of 84.24, indicating a relatively higher water content, while Mini-Kazeneza (Aeroponic) has the lowest mean at 55.93, suggesting drier potatoes. Additionally, the standard deviations (SD) highlight the variability within each category, with Mini-Gikungu (Aeroponic) having the smallest SD (0.15), signifying consistent moisture levels, and Mini-Kinigi (Aeroponic) showing the largest SD (0.69), indicating greater variability. The range of moisture content, r\0-=-0987689098765epresented by the minimum (Min) and maximum (Max) values, varies across these categories, with Pre-base Gikungu INES displaying the widest range (Min: 92.38, Max: 93.00) and Pre-base Kinigi INES showing the narrowest range (Min: 74.89, Max: 76.06).



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Table 1 also presents a wide range of seed types and farming methods, offering insights into potential starch content in Irish potatoes. Based on results presented, Mini-Kazeneza (Aeroponic) demonstrates a relatively high mean starch content of 82.62, indicating it may yield potatoes with abundant starch. Conversely, Mini-Gisubizo (Aeroponic) has a lower mean of 58.31, suggesting lower starch content. Starch content depends on both genetics (the seed type) and environmental factors (farming method).

The standard deviation values highlight variability within each category, which is crucial for maintaining consistent starch quality in potato production. Moreover, for processors and marketers seeking specific starch content, the data can guide the selection of potatoes with desired characteristics, like the Kinigi product from Musanze, with a mean starch content of 64.67.

TABLE 1. Moisture and starch content of Irish potato samples

| Sample No. | Sample name | Moisture content | Starch |
|---|---|---|---|
| 1 | Mini-Ndamira (Aeropinic) | 79.91 ± 0.31 | 62.4 ± 1.51 |
| 2 | Mini-Kazeneza (Aeroponic) | 55.92 ± 0.49 | 82.62 ± 0.66 |
| 3 | Pre-base Kazeneza | 68.18 ± 0.20 | 76.59 ± 0.41 |
| 4 | Pre-baseKinigi | 66.90 ± 0.47 | 77.31 ± 0.52 |
| 5 | Mini-Gisubizo(aeroponic) | 81.89 ± 0.20 | 58.31 ± 0.89 |
| 6 | Pre-base Kirundo | 69.84 ± 0.36 | 70.22 ± 0.34 |
| 7 | Mini-Kinigi (aeroponic) | 84.23 ± 0.69 | 60.12 ± 0.80 |
| 8 | Pre-base Cyerekezo | 77.30 ± 0.65 | 68.52 ± 0.46 |
| 9 | Mini-Ndeze (aeroponic) | 76.16 ± 0.48 | 66.78 ± 0.57 |
| 10 | Mini-Gikungu (aeroponic) | 83.94 ± 0.15 | 59.34 ± 0.99 |
| 11 | Mini-Cyerekezo (aeroponic) | 81.29 ± 0.28 | 61.66 ± 0.74 |
| 12 | Mini-Gikungu (Convention) INES | 72.91 ± 0.30 | 78.11 ± 0.32 |
| 13 | Mini-Kinigi (Convention) INES | 72.84 ± 0.77 | 77.63 ± 0.48 |
| 14 | Mini-Kirundo (Convention) INES | 77.81 ± 0.51 | 74.24 ± 1.01 |
| 15 | Pre-base Kinigi INES | 75.31 ± 0.65 | 68.62 ± 1.02 |
| 16 | Pre-base Kirundo INES | 73.88 ± 0.21 | 64.39 ± 2.36 |
| 17 | Pre-base Gikungu INES | 92.67 ± 0.31 | 42.13 ± 1.49 |
| 18 | Mini-Kinigi (Convention) Kinigi | 73.16 ± 0.78 | 78.53 ± 0.90 |
| 19 | Mini-Kirundo (Convention) Kinigi | 78.24 ± 0.49 | 65.33 ± 1.09 |
| 20 | Kinigi product from market (Musanze) | 70.34 ± 0.45 | 64.67 ± 0.34 |
| 21 | Kirundo product from market (Musanze) | 75.32 ± 0.55 | 63.21 ± 0.37 |
| 22 | Gikungu product from market (Musanze) | 78.62 ± 0.61 | 60.12 ± 1.07 |

### *3.2. Analysis of moisture content, mineral composition and nutritional attributes of tomatoes*

Data presented in Table 2 are summary showing differences in the nutritional composition of tomatoes from a screen house compared to tomato products from the market.

Based on results, tomatoes from the screen house have slightly higher moisture content, implying they might be fresher than market tomatoes. Regarding minerals (Ca, P, Fe, Mg), Screen house tomatoes generally have higher levels of calcium, phosphorus, iron, and magnesium, which suggests they may offer better mineral content than market tomatoes.

In terms of carbohydrates, Fibers, and Ash, it was noted that screen house tomatoes have more carbohydrates and fibers, indicating potentially better nutritional and fiber content. Additionally, screen house tomatoes contain higher levels of vitamin C and carotenoids, which are valuable antioxidants contributing to their nutritional quality. Overall, it can be said that screen house tomatoes may offer better nutritional quality compared to market tomatoes.

TABLE 2. Moisture content, mineral composition and nutritional attributes of tomatoes

| Parameter | Tomato from screen house<br>Mean | Tomato product from market<br>Mean |
|---|---|---|
| **Moisture content** | 94.23 ± 0.07 | 92.53 ±0.51 |
| **Ca(mg/100gr)** | 82.23 ± 0.21 | 78.55 ± 0.98 |
| **P(mg/100g)** | 54.80 ± 0.18 | 48.00 ± 0.97 |
| **Fe(mg/100g)** | 1.62 ± 0.01 | 0.84 ± 0.06 |
| **Mg(%)** | 6.64 ± 0.06 | 4.21 ± 0.03 |
| **Carb(mg/100g)** | 3.74 ± 0.11 | 2.87 ± 0.05 |
| **Fibers(mg/100g)** | 1.18 ± 0.02 | 0.92 ± 0.09 |
| **Ash(%)** | 0.81 ± 0.04 | 0.60 ± 0.00 |
| **VIt C(%)** | 2.26 ± 0.04 | 1.86 ± 0.09 |
| **carotenoids(mg/100g)** | 3.81 ± 0.50 | 1.92 ± 0.16 |

### *3.3. Analysis of moisture content, mineral composition and nutritional attributes of carrots*

Table 3 presents results for carrots from the screen house compared to those from market. Based on results, tomatoes from screen house have a slightly higher moisture content (SD = 0.12) with a mean of 88.89, indicating their freshness, while market carrots exhibit a slightly lower moisture content (SD = 0.69) and a mean of 86.12, implying that they might be relatively drier with a greater variation in moisture levels. Minerals (Ca, P, Fe, Mg). In addition to this, screen house carrots have higher levels of minerals, as evidenced by the higher means, and generally lower standard deviations, indicating a more consistent mineral content. In contrast, market carrots have lower means and, in some cases, higher standard deviations, suggesting greater variability in mineral content.

TABLE 3. Moisture content, mineral composition and nutritional attributes of carrots

| Parameter | Carrot from screen house<br>Mean | Carrot from market<br>Mean |
|---|---|---|
| **Moisture content** | 88.89 ± 0.12 | 86.12 ± 0.69 |
| **Ca(mg/100gr)** | 80.00 ± 1.31 | 34.00 ± 0.11 |
| **P(mg/100g)** | 53.00 ± 0.17 | 25.00 ± 0.79 |
| **Fe(mg/100g)** | 2.50 ± 0.30 | 1.80 ± 0.15 |
| **Mg(%)** | 9.21 ± 0.19 | 6.98 ± 0.09 |
| **Carb(mg/100g)** | 10.46 ± 0.67 | 6.12 ± 0.24 |
| **Fibers(mg/100g)** | 2.38 ± 0.04 | 1.16 ± 0.20 |
| **Ash(%)** | 1.16 ± 0.21 | 0.42 ± 0.01 |
| **VIt C(%)** | 3.65 ± 0.18 | 0.34 ± 0.03 |
| **carotenoids(mg/100g)** | 4.84 ± 0.17 | 2.34 ± 0.28 |



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Referring to carbohydrates, fibers, and ash it can be seen that carrots from the screen house contain higher levels of carbohydrates and fibers with relatively lower standard deviations, suggesting potentially better nutritional and fiber content with consistency. It can also be noted that screen house carrots also contain higher levels of vitamin C and carotenoids with smaller standard deviations, which indicates consistency in these essential antioxidants contributing to their nutritional quality. Generally, results suggest that screen house carrots not only offer better nutritional quality compared to market carrots but also exhibit lower standard deviations, indicating more consistent quality.

### *3.4. Analysis of moisture content, mineral composition and nutritional attributes of Bell peppers*

Data presented in Table 4 compares bell peppers sourced from a screen house and bell pepper products from the market, focusing on various parameters that shed light on their quality and nutritional characteristics. Based results presented regarding moisture Content, bell peppers from the screen house have a slightly higher moisture content with a mean of 90.03, and a relatively low standard deviation (SD = 0.19), indicating that they fresh and also consistent in moisture content. In contrast, bell pepper products from the market exhibit a lower mean moisture content (86.22) with a slightly higher standard deviation (SD = 1.00), suggesting that there is more variability in moisture content among market bell peppers.

Considering minerals (Ca, P, Fe, Mg) also the screen house bell peppers tend to have higher mean values for minerals such as calcium (Ca), phosphorus (P), iron (Fe), and magnesium (Mg). Additionally, the standard deviations for these minerals are generally lower for screen house bell peppers, implying greater consistency in mineral content compared to market bell peppers.

TABLE 4. Moisture content, mineral composition and nutritional attributes of bell peppers

| | **Bell pepper from screen house** | **Bell pepper product from market** |
|---|---|---|
| **Parameter** | **Mean** | **Mean** |
| **Moisture content** | 90.03 ± 0.19 | 86.22 ± 1.00 |
| **Ca(mg/100gr)** | 6.48 ± 0.19 | 4.32 ± 0.11 |
| **P(mg/100g)** | 25.34 ± 0.98 | 21.40 ± 0.46 |
| **Fe(mg/100g)** | 0.38 ± 0.04 | 0.11 ± 0.03 |
| **Mg(%)** | 10.80 ± 0.51 | 6.33 ± 0.23 |
| **Carb(mg/100g)** | 4.86 ± 0.28 | 3.12 ± 0.11 |
| **Fibers(mg/100g)** | 2.03 ± 0.10 | 1.60 ± 0.12 |
| **Ash(%)** | 1.06 ± 0.06 | 0.45 ± 0.06 |
| **VIt C(%)** | 0.23 ± 0.02 | 0.01 ± 0.00 |
| **carotenoids(mg/100g)** | 6.19 ±0.88 | 5.88 ± 0.44 |

Based on results presented on carbohydrates, fibers, and ash, bell peppers from the screen house exhibit higher mean values for carbohydrates and fibers, and their standard deviations are generally lower. Generalizing this, it can be said that screen house bell peppers may offer better nutritional and fiber content with greater consistency. The ash content also reflects lower variability in mineral composition for screen house bell peppers. Referring to Vitamin C and Carotenoids also, screen house bell peppers have higher mean values for vitamin C and carotenoids with smaller standard deviations, indicating not only higher nutritional quality but also consistency in the levels of essential antioxidants. Putting all this together, the data suggest that bell peppers from the screen house may offer better nutritional quality and more consistent quality compared to bell pepper products from the market.

### *3.3. Pesticides residues in vegetable samples*

Chemicals known as pesticides are sprayed on crops at different phases of their growth as well as when they are being stored after harvest. The goal of using pesticides is to increase plant quality and prevent agricultural pests or undesirable plants from destroying food crops. Farm production has increased as a result of the usage of pesticides in commercial agriculture. Pesticides have many advantages in agriculture, but if they are applied incorrectly, the produce that is sold to customers may have high and unwanted concentrations of the chemicals. These include inappropriate selection of pesticides used on food stuffs, over use of pesticides and harvesting the crops before the residues have washed off after application (Bakirci et al., 2014).

Table 5 reveals that bell peppers were low in pesticide residues, as alpha-cypermethrin, cypermethrin, and Dethane were not detected in the samples. This denotes that the quality of analyzed samples may not cause any harmful effect to the consumers.

TABLE 5. Pesticides residues in vegetable samples

| **Sample name** | **Alpha cypermethrin** | **Cyperme thrin** | **Dethan e** |
|---|---|---|---|
| Tomato product from screen house (Kamonyi) | | Not detected | Not detected |
| Tomato product from market (Kicukiro) | | Not detected | Not detected |
| Carrot product from screen house (Kamonyi) | Not detected | Not detected | Not detected |
| Carrot product from market (Kicukiro) | Not detected | Not detected | Not detected |
| Bell pepper product from screen house | Not detected | Not detected | Not detected |
| Bell pepper product from market | Not detected | Not detected | Not detected |

### *3.4. Comparison of moisture content between farming types of irish potatoes*

To do this, average content moisture and starch for irish potatoes for each farming types namely mini-aeroponic, prebase and mini convention was calculated and the following is the graph illustrating them. According to this Figure 1, it can be seen that for both min-aeroponic and prebase, the average moisture content is higher than average starch. For min-convention both moisture and starch have almost similar values on average for samples taken.

## IV. CONCLUSION

The present analyses show how important and helpful the screen houses are in the control of environmental conditions that might affect the overall quality of agricultural produces especially fruits and vegetables (horticultural crops). The findings of this analysis suggest that fruits and vegetables from the screen house may offer better nutritional quality and more consistent quality compared to those products from the market.

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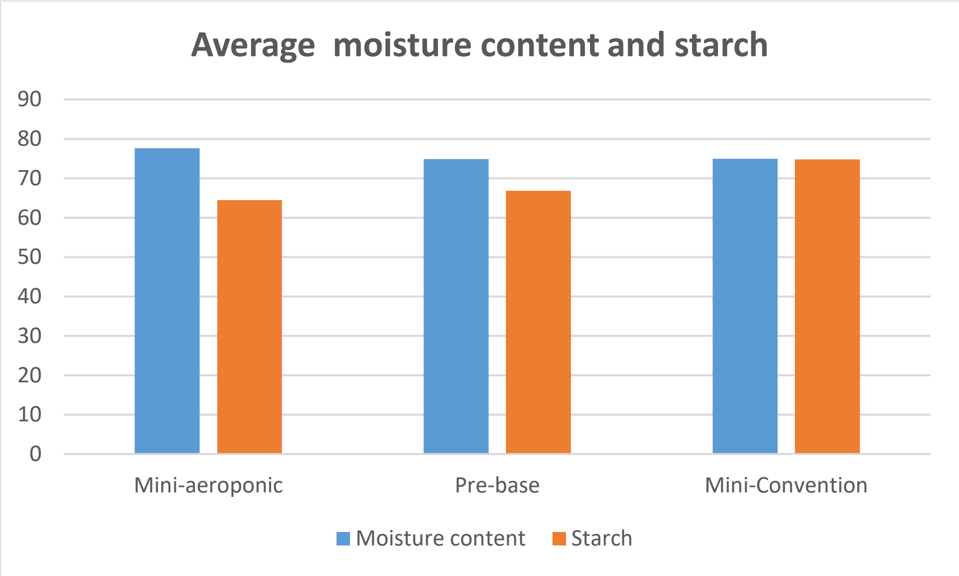


Figure 1. Comparison of moisture content of irish potatoes from different farming types

In addition, there was no detectable pesticides residues were found in all produces, denoting the good quality of produces in terms of safety to human health. Therefore, the use of screen houses and other measures to control environmental impact on horticultural commodities are highly recommended.

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*Conflict of Interest*

The authors declare that there is no conflict of interest.

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