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Effect of seasonal shift on the proximate nutritional composition of some plant materials from the aquaponics farming

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A B S T R A C T

This study intends to evaluate the variations of the proximate nutritional makers of some plant samples [red chili (RCH) fruit, red tomato (RTO) fruit, green spinach (GSP) leaf, and green lettuce (GLE) leaf] from aquaponics farming in relation to seasons. The research was carried out for the duration of four (4) periods (winter, spring, summer, and autumn). The proximate nutritional parameters determined were total moisture (TMO), crude ash (CAS), crude fiber (CFI), total carbohydrate (TCA), and soluble protein (SPR). The CAS, CFI, TCA, and SPR levels of the RCH, RTO, GSP, and GLE plant materials are significantly ($P<0.05$) difference among seasons. The CAS, CFI, TCA, and SPR amounts of each experimental plant materials increases significantly ($P<0.05$) in the summer in comparison to winter, spring, and autumn. However, the TMO content of above plant samples was detected to increase significantly ($P<0.05$) in the winter season. The findings of this research indicated that shifts in the seasonal factors such as temperature, solar intensity, and daylight length have revealed differences in the proximate nutritional indices of the study plant materials from aquaponics farming.

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1. Introduction

The aquaponics system is a sustainable farming method for the simultaneous production of fish and plants (Diver, 2006). Globally, the system is gaining recognition towards achieving sustainable food production to revert hunger and starvation, malnutrition, and poverty in urban and rural communities (Love et al., 2015). Hence, this farming method could be of great advantage to the African countries with limited resources for agricultural production (Mchunu, 2018). The technology is new to the African countries, with a few cited research articles on the theme (Obirikorang et al., 2021). From an international survey carried out in 2014 on this technology, responses were only received from South Africa and Ghana (Love et al., 2015). From the 15 African nations, the total published articles in aquaponics studies were 82. Egypt, South Africa, and Kenya appear to have widely adopted the technology, with 23, 20, and 14 published research papers, respectively. Nigeria had 9 articles, and the remaining countries had between 1 and 3 articles (Obirikorang et al., 2021).

The system could provide a solution to the majority of problems associated with food supply to feed the growing populace (Castro et al., 2006; Diver, 2006). The farming system can enable the production of more plants per square foot due to closer the proximity of planting compared with conventional practice that needs large tracts of land (Rakocy and Hargreaves, 1993). In addition, roots absorb required nutrients without competition with non-edible plants such as weeds in comparison to traditional agricultural method that requires fertilizer application (Savidov, 2004; Savidov and Hutchings, 2005). Also, the technology is usually set up in a greenhouse to limit the adverse effects of pests, and insects to promote rapid growth rates, high yields, and more nutritious products (Blidariu and Grozea, 2011; Brook, 2017). Furthermore, the system has the potential to offer a lasting solution to most of the issues of phosphorus, nitrogen runoff, and environmental pollution linked to traditional farming operation (Timmons et al., 2002; Flavius and Grozea, 2011).

The selection of the experimental plant materials (red chili fruit, red tomato fruit, green spinach leaf, and green lettuce leaf) is mainly because of their nutritional constituents. They are also among the most commonly grown and regularly consumed fruit and leafy plants globally.

Mudzengi et al. (2020) and Castro et al. (2021), reported the relationship between plants and seasonal variations in semi-arid zones. To another report, productivity and constituents of plants are determined by group of factors such as change in climate (Herrera et al., 2017). Additionally, Adeyeye (2005) cited that the growth and development of crops were often influenced by changes in the weather factors such as temperature and intensity of solar radiations. Therefore, this study intends to find out and describe the impacts of seasonal shifts on the proximate nutritional properties of red chili fruit, red tomato fruit, green spinach leaf, and green lettuce leaf plant materials from aquaponics farming.

2. Materials and methods

2.1. Study site, system setup, and operation

The experimental aquaponics system was located in Makhanda, Eastern Cape of South Africa. The study was conducted for consecutive four (4) seasons (winter, spring, summer, and autumn). The investigation commenced in the winter, from the 29th of June 2020 to the 31st of August 2020. The spring research was carried out from the 3rd of September 2020 to the 30th of November 2020. The summer experiment began from the 3rd of December 2020 to the 1st of March 2021. Finally, the autumn evaluation started on the 4th of March 2021 and ended on the 27th May 2021.

The aquaponics system setup was as a coupled commercial system enclosed in a greenhouse and only exposed to ambient sun light. It consisted of 4 × 1,500 L fish water tanks; 2-sump tanks (1 × 1,500 L; 1 × 500 L), each with an associated submersible pump (SOBO®, WP-7000, 105W, 5000L/H); 20 × 400 L flood-and-drain gravel stones media beds; and 24 × 900 L deep-water culture tanks. PVC pipes connected the system's components to form a closed loop. The fish tanks and sumps were placed in a separate housing unit within the aquaponics greenhouse.

The water from the 4-fish tanks first flowed to the single sump tank (1 × 1,500 L) by gravity, then pumped to gravel stones media beds. As the water volume in flood and drain media beds reached its highest level, it drained into deep-water hydroponics tanks by gravity through PVC pipe outlets. Water from the deep-water culture tanks was all fed directly into the second single sump (1 × 500 L), which was eventually delivered to fish rearing tanks, thus, completing a cycle. The flood-and-drain system was maintained by bell siphons installed in each gravel stones media bed.

2.2. Plant materials, supplementation, and water replacement

In this study, the plant materials used were Bird's eye red chili (*Capsicum frutescens* L.) fruit, red cherry tomato (*Solanum lycopersicum*) fruit, green Silver-beet spinach (*Spinacia oleracea*) leaf, and green Locarno lettuce (*Lactuca sativa* L.) leaf. The research plants were collected each season for nutritional composition assessment. The red chili fruit was obtained from gravel stone media-bed I and II, denoted by GMB-I and GMB-II. Besides, each red tomato fruit and green spinach leaf was collected from gravel stone media-bed III and IV (GMB-III and GMB-IV), respectively. Nevertheless, the green lettuce leaf was acquired from a polystyrene sheet on deep-water culture-1 (DWC-1).

The supplementation (iron-chelating, buffering, and manufactured organic food addition) and water replacement were made to the system over the study period. During the winter season, on the 3rd of July 2020, 13th of July 2020, and 17th of August 2020; iron chelate (500 g), calcium hydroxide (450 g), and potassium hydroxide (450 g) were added to the system through the sump, respectively. Furthermore, in the spring, on the 10th of September 2020, 10th of October 2020, and 22nd of October 2020; 2.0 L of Sea-Grow (manufactured organic plant food), 1000 L of fresh rainwater stored in the reservoir, and 2.0 L of Sea-Grow were added. In addition, during the summer period, 1000 L of fresh rainwater, 2.0 L each of Sea-Grow and Sea- Brix (manufactured organic plant foods), and 500 g of iron chelate were added to the system on the 5th of December 2020, 14th December 2020, and 22nd January 2021, respectively. Finally, in the autumn season, neither supplementation nor water replacement was made to the aquaponics system.

2.3. Chemical reagents and apparatus

The chemical reagents used were sodium hydroxide (Merck, Batch No. MB1M610352), concentrated sulfuric acid (Merck Chemicals, Batch No. 42980), HPLC-grade methanol (Merck, CAS-No. 67-56-1, Germany), glucose (Merck Chemicals, Germany), lead acetate (Sigma Aldrich, CAS Number: 546-67-8), bovine serum albumin (Sigma Aldric, CAS No. 9048-46-8), and Bradford reagent (Sigma Life Science, Lot No. SLBP3810V). The equipment included Benchtop laboratory oven (Labcon laboratory equipment, Krugersdorp, South Africa), muffling furnace (Gallenkamp muffle furnace, REX C900, England), refrigerated centrifuge (Heraeus Megafuge 1.0R, Germany), Epoch UV-vis microplate reader spectrophotometer (EPOCH2C, Bio-Tek Instruments, Inc., USA), analytical balance (RADWAG, 220 g × 0.1 mg, Model, AS/220/C/2, Poland), silica crucible dishes, Büchner funnel, moisture dishes, desiccator, and heating plate (Fied Electric, Model MI-4, Haifa, Israel). The consumables were Milli-Q water (EMD-Millipore machine Model 13681), Whatman filter paper (125 mm, 11 μm, Maidstone, England), and Eppendorf tubes.

2.4. Total moisture determination

2.4.1. Experimental procedure

The total moisture determination was carried out per the method of International Association of Official Analytical Chemists (AOAC, 2005). Moisture dishes were washed with Mili-Q water, oven-dried at 105 °C for 3 h, cooled in a desiccator for 30 min, and weighed (W1). Different weights (1, 2, and 3 g) of each plant material (red chili fruit, red tomato fruit, green spinach leaf, and green lettuce leaf) were added into moisture dishes and weighed (W2). The moisture content of each plant sample was obtained by constant weight drying for 12 h at 105 °C Each sample was then cooled in a desiccator for 30 min and weighed (W3). The percentage of total moisture was calculated using the following relations:

$$\% \text{ Total moisture} = \frac{W_2 - W_3}{W_{2-W_1}} \times 100$$

Where: W1 = initial weight of empty moisture dishes

W2 = weight of moisture dishes + samples before drying

W3 = Final weight of moisture dishes + samples after drying

2.5. Crude ash determination

2.5.1. Experimental procedure

The procedure was conducted as described by the International Association of Official Analytical Chemists' method (AOAC, 2005). Empty crucibles were weighed (W1). Various weights (1, 2, and 3 g) of each previously oven dried (105 °C for 3 h) plant material (red chili fruit, red tomato fruit, green spinach leaf, and green lettuce leaf) was added into crucibles and weighed (W2). They were incinerated in a muffle furnace at 550 °C for 6 h, allowed to cool in a desiccator for 1 h, and weighed (W3). The percentage of crude dry ash was determined as follows:

$$\% \text{ Crude Ash} = \frac{W_3 - W_1}{W_{2-w_1}} \times 100$$

Where: W1 = weight of empty crucibles

W2 = weight of crucibles + samples before incineration

W3 = weight of crucibles + samples after incineration

2.6. Crude fiber analysis

2. 6.1. Experimental procedure

The crude fiber analysis was done as explained by the method of International Association of Official Analytical Chemists (AOAC, 2005). Different weights (1, 2, and 3 g) of each previously oven dried plant material (red chili fruit, red tomato fruit, green spinach leaf, and green lettuce leaf) were weigh out (W1) and placed in round bottom flasks. To each plant sample in the round bottom flask, 100 mL sulphuric acid solution (0.25 M) was added. Each mixture was boiled under reflux for 30 min with continuous swirling. Each mixture was then filtered under suction using a Buchner funnel. The insoluble fiber (residue) of each plant sample was washed thoroughly with boiling Milli-Q water until acid-free. The acid-free insoluble residue of each plant was transferred to a second round bottom flask and 100 mL of 0.30 M sodium hydroxide solution was added. Each mixture was boiled under reflux for 30 min with continuous swirling. Each mixture was then filtered with a Whatmann No. 1 filter paper under suction and washed with boiling Milli-Q water until base-free. Each insoluble residue was air-dried in an oven at 105 °C for 3 h, cooled in a desiccator for 30 min, and weighed (W2). Finally, each dried residue was incinerated at 550 °C for 6 h in a muffle furnace, cooled in a desiccator, and weighed (W3). The percentage crude fiber content was calculated using the formula:

$$\%\text{Crude Fiber} = \frac{W_2 - W_3}{W_1} \times 100$$

2.7. Total carbohydrate determination

2.7.1. Sample extraction

Each plant sample extraction was carried out as reported by Mannem et al. (2012), with modification in sample weight and volume of methanol added. To each 10 g of multiple dried sample, 50 mL of 80% HPLC-grade methanol was added. Each mixture was boiled on a heating plate for 5 min and allowed to stand for 30 min to complete extraction. Each extract was filtered through Whatman No. 1 filter paper. The various filtrates were oven dried at 70 °C to remove methanol. To generate a 1.0 mg mL^{-1} sample solution, 1 mg of each residue was dissolved in 1.0 mL of 0.1 M Lead acetate (clarifying agent) solution and vortexed. Each solution was then centrifuged at 2,000 RCF × g for 5 min. Lastly, the supernatant of each sample solution was diluted with Milli-Q water in a ratio of 1:25 and determined for total carbohydrate content.

2.7.2. Standard preparation

A glucose stock solution was prepared by dissolving 5.0 mg of glucose crystals in 1.0 mL of Milli-Q water. A working standard solution of 500 μg mL^{-1} was generated from the stock. Different concentration values of 25, 50, 100, 200, and 300 μg mL^{-1} were made from the working standard by dilution with Milli-Q water.

2.7.3. Experimental procedure

The procedure was conducted as reported by Albalasmeh et al. (2013). This procedure is analogous to the phenol–sulfuric acid method of DuBois et al. (1956). An aliquot of 250 μL of each sample solution was mixed with 50 μL of ice-cooled concentrated sulfuric acid (98.9%). Each reaction mixture was then vortexed for 30 s and incubated for 2 min at room temperature (25±5 °C). The absorbance of each reaction mixture was read at 315 nm against a reagent blank, using a 96-well plate reader.

2.8. Soluble protein determination

2.8.1. Sample extraction

Protein extraction from each plant material was done as reported by Barman et al. (2015), with modifications in sample weight and volume of phosphate buffer added. To 1.0 g of each multiple dried sample, 25 mL of a cold phosphate buffer (0.1 M, pH 7.4) was added. Each sample mixture was kept overnight at 4 °C to extract the protein completely. The various samples were centrifuged (4,000 RCF × g) at 4 °C for 20 min and filtered with Whatman No. 1 filter paper.

2.8.2 Standard preparation

To 5 mg of bovine serum albumin crystals, 1.0 mL of distilled water was added to produce a stock solution of 5 mg mL^{-1}. A standard working solution of 500 μg mL^{-1} was generated from the stock solution. Different concentration levels of 50, 100, 200, 300, 400, and 500 μg mL^{-1} were made from the working standard by dilution with Milli-Q water.

2.8.3. Experimental procedure

The assay was performed as described by Bradford (1976). To 200 μL of each sample extract, 1.20 mL of the reagent (Bradford reagent) was added and mixed. Each sample mixture was allowed to stand for 15 min at room temperature (25±5 °C). The absorbance of each mixture was read at a wavelength of 595 nm against the reagent blank using a 96 well plate reader.

2.9. Statistical analysis

All data obtained from this research were statistically evaluated with repeated-measures analysis of variance (RM ANOVA). The level of significance applied was 5%. As the RM ANOVA revealed a significant difference among seasons, a post-hoc test using unpaired student's t-test is performed to detect the position where the significant difference between seasons occurred.

3. Results and discussion

Tables 1 to 5 depict the results for the total moisture, crude ash, crude fiber, total carbohydrate, and soluble protein contents, respectively, of the plant materials for the comparative seasonal research.

3.1. Total moisture

In this research, the total moisture (TMO) level of the red chili (RCH) fruit (fresh weight basis) indicated no significant ($P>0.05$) different in the winter, spring, and autumn, however, statistically different in the summer period. (Table 1). There was a notable significant ($P<0.05$) variation in the TMO of the red tomato (RTO) fruit among the comparative four (4) seasons (Table 1). The TMO of the green spinach (GSP) leaf and green lettuce (GLE) leaf were significantly ($P<0.05$) varied among the winter, spring, and summer. The TMO of the GSP and GLE detected in autumn were similar to those obtained in the summer and spring (Table 1). In this research, the winter indicated the highest TMO for the RCH, RTO, GSP, and GLE plant materials (Table 1).

Table 1. Seasonal changes in the total moisture content

	Total moisture (%)			
	Plant materials (n = 3)			
Seasons	RCH, fw	RTO, fw	GSP, fw	GLE, fw
Winter	74.17±1.20^{a}	88.79±0.78^{a}	92.40±0.61^{a}	94.71±0.48^{a}
Spring	71.82±0.33^{a}	83.41±1.81^{b}	90.04±0.21^{b}	90.54±0.21^{b}
Summer	67.25±2.05^{b}	72.16±0.89^{d}	86.56±1.23^{c}	87.25±0.52^{c}
Autumn	73.82±1.94^{a}	79.52±1.02^{c}	88.18±0.49^{bc}	88.52±2.19^{bc}

fw = fresh weight, RCH = red chili fruit, RTO = red tomato fruit, GSP = green spinach leaf, GLE = green lettuce leaf, n = number of repeats of each plant sample. The results were expressed as mean±SD. Values with different superscript letters between seasons in a column are significantly (P<0.05) different from each other.

There were no reports on the influence of seasonal changes on the TMO level of the RCH, RTO, GSP, and GLE plant materials. Notwithstanding, the TMO level of the RCH fruit of the present work was lower than the finding (93.00±1.80%) of Dalhatu et al. (2018) of the Nigerian *Capsicum annum* from open and solar drying. Likewise, the observed TOM level for the RTO fruit was lower compared with the reported value (93.50±0.21%) by Hanif et al. (2006). The TMO content of the GSP leaf of this research was compatible with the cited value (94.20±0.04%) of Singh and Sehgal (2001). However, higher than the reported level (81.72±0.40%) from soil farming method by Sani et al. (2011). Nevertheless, the TMO of the GLE leaf of this study was lower than the amount reported for different cultivar from rainy (12.58±1.36) and dry (12.58±1.36) seasons (Birnin-Yauri et al., 2011).

The winter period and GLE leaf revealed the highest TMO level in this study (Table 1). The higher TMO revealed by the study plants (RCH, RTO, GSP, and GLE) in the winter could be linked to the characteristic low temperature and transpiration rate characteristics of the season. In this current research, seasonal changes have induced variations in the TOM levels of the RCH, RTO, GSP, and GLE plant materials.

3.2. Crude ash

A significant (P<0.05) difference in the crude ash (CAS) content (dry weight basis) of the red chili (RCH) fruit, red tomato (RTO) fruit, green spinach (GSP) leaf, and green lettuce (GLE) leaf was detected among the comparative seasons. The highest CAS level of the RCH, RTO, GSP, and GLE plant samples was obtained in the summer (Table 2). The RCH possessed the highest CAS content in this season (summer).

Table 2. Seasonal variations in the crude ash content

	Crude ash (%)			
	Plant materials (n = 3)			
Seasons	RCH, dw	RTO, dw	GSP, dw	GLE, dw
Winter	10.17±0.02^{d}	0.87±0.01^{d}	0.49±0.06^{d}	0.48±0.06^{d}
Spring	11.78±0.43^{c}	1.22±0.07^{c}	0.76±0.17^{c}	0.81±0.12^{c}
Summer	13.47±0.32^{a}	1.74±0.05^{a}	1.64±0.29^{a}	1.54±0.23^{a}
Autumn	12.16±0.09^{b}	1.39±0.05^{b}	1.26±0.09^{b}	1.13±0.27^{b}

dw = dry weight, RCH = red chili fruit, RTO = red tomato fruit, GSP = green spinach leaf, GLE = green lettuce leaf, n = number of repeats of each plant material. The results were resented as mean±SD. Values with different superscript letters between seasons in a column are significantly (P<0.05) different from each other.

The effect of seasonal variations on the CAS level was lacking in the existing literature. However, the CAS value of the RCH fruit obtained in this experiment was compatible with the amount (10.67±1.89%) reported by Dalhatu et al. (2018) for the open and solar drying *Capsicum annum* from Nigerian. But, higher than the finding (6.26±0.15%) of Sharma et al. (2017). The CAS percentage of the RTO fruit of the present research was higher compared with the amount (0.80±0.01%) reported by Hanif et al. (2006). Similarly, the CAS level of the GLE leaf of this work (summer and autumn periods) was higher than the reported amount (0.90±0.05%) of Hanif et al. (2006). However, lower than values obtained in the winter and spring. It is only in the summer and autumn that the GSP leaf indicated a higher CAS content in comparison to the finding (1.10±0.15%) of Hanif et al. (2006).

From finding (1.9±0.02%) of Bangash et al. (2011) and the cited value (1.71±0.09%) by Barman et al. (2015), the CAS level of the GSP leaf sourced from normal ground cultivation was not in support to the detected amount of this experiment. The elevated CAS amount observed during the summer season and the RCH fruit may be attributed to an augmented mineral composition, farming method, and or cultivar type (Nuri et al., 2014). In this study, seasonal differences have induced differences in the CAS value of the experimental plants.

3.3. Crude fibre

There was significant (P<0.05) difference in the crude fiber (CFI) amount (dry weight basis) of the red chili (RCH) among the experimental four (4) periods (Table 3). Although there was no significant (P>0.05) difference between spring and autumn values for the RTO and GLE plant materials and between summer and autumn values for the GSP, a significant (P<0.05) differences were found between other seasonal comparisons of the CFI values of these plants (RTO, GSP, and GLE) (Table 3).

Table 3. Seasonal differences in the crude fibre content

	Crude fiber (%)			
	Plant materials (n = 3)			
Seasons	RCH, dw	RTO, dw	GSP, dw	GLE, dw
Winter	19.87±0.28^{d}	9.28±0.29^{c}	4.89±0.08^{c}	10.29±0.2^{c}
Spring	23.71±1.05^{c}	16.90±0.79^{b}	6.46±0.62^{b}	11.70±0.36^{b}
Summer	38.21±2.90^{a}	19.29±1.14^{a}	9.78±0.64^{a}	13.84±0.33^{a}
Autumn	32.06±0.41^{b}	17.67±0.25^{b}	8.67±0.24^{a}	11.95±0.23^{b}

dw = dry weight, RCH = red chili fruit, RTO = red tomato fruit, GSP = green spinach leaf, GLE = green lettuce leaf, n = number of repeats of each vegetable plant. The results were expressed as mean±SD. Values with different superscript letters between seasons in a column are significantly (P<0.05) different from each other.

The highest CFI content for the RCH, RTO, GSP, and GLE plant samples was indicated in the summer (Table 3). The higher CFI content obtained in the summer could be due the observed increased in the biomass accumulation and cultivation practice differences (Nuri et al, 2014). The RCH fruit revealed the highest CFI value compared with RTO, GSP, and GLE plants materials (Table 3). The influence of seasonal impact on the percentage CFI of the RCH, RTO, GSP, and GLE plant materials was not detected in the previous studies. Notwithstanding, the CFI value of the RCH fruit in this research was higher than the finding (18.33±0.76%) of Dalhatu et al. (2018) of the Nigerian capsicum annum from open and solar drying. The CFI content for each RTO fruit, GSP leaf, and GLE leaf of this research was greater than the obtained levels of 0.3±0.07%, 0.6±0.01%, and 0.7±0.20% in tomato, spinach, and lettuce, respectively, by Hanif et al. (2006). In this experimental work, the CFI amounts of the evaluated plant samples have been affected by seasonal changes.

3.4. Total carbohydrate

In this study, the statistical analysis of the data revealed that the total carbohydrate (TCA) content of plant samples on a dry weight basis exhibited significant (P < 0.05) differences in different seasons (Table 4). However, there was no significant (P>0.05) difference between the values of the red chili (RCH) fruit observed in the winter and spring, between the values of the red tomato (RTO) fruit and green spinach (GSP) leaf observed in the spring and autumn, and between the values of the green lettuce (GLE) leaf obtained in the spring and summer. The summer revealed the highest TCA among the comparative seasons (Table 4).

Table 4. Seasonal variations in the total carbohydrate

	Total carbohydrate (%)			
	Plant materials (n = 3)			
Seasons	RCH, dw	RTO, dw	GSP, dw	GLE, dw
Winter	4.75±0.04^{c}	5.03±0.01^{c}	1.01±0.01^{c}	2.55±0.03^{c}
Spring	5.01±0.04^{c}	5.44±0.04^{b}	2.00±0.05^{b}	3.57±0.07^{a}
Summer	5.98±0.01^{a}	6.91±0.06^{a}	2.89±0.08^{a}	3.77±0.01^{a}
Autumn	5.74±0.08^{b}	5.45±0.05^{b}	2.05±0.06^{b}	2.92±0.23^{b}

dw = dry weight, RCH = red chili fruit, RTO = red tomato fruit, GSP = green spinach leaf, GLE = green lettuce leaf, n = number of repeats of each plant sample. The results were given as mean±SD. Values with different superscript letters between seasons in a column are significantly (P<0.05) different between seasons.

Among the experimental plant materials, it was observed that the RCH exhibited higher TCA values than the other samples in the autumn, while the RTO exhibited the highest values in all other seasons. The impact of seasonal variations on the TCA amounts of the RCH, RTO, GSP, and GLE plant samples in not found in the existing repots. Nevertheless, the percentage TCA for the RCH fruit obtained in this research was higher compared with finding of Ananthan et al. (2014) of six (6) different cultivars sourced from local markets, which range between 1.96±0.09% to 2.71 ± 0.06%. However, much lower than the reported value (66.40±1.3) of Dalhatu et al. (2018) from the Nigerian capsicum annum. The total TCA for RTO fruit of this study was higher in comparison to the value (3.90±0.10%) obtained by Hanif et al. (2016). The reported TCA amount of (2.92±0.05), (2.93±0.04%), and (4.00±0.12%) by Asaolu et al. (2012), Barman et al. (2015), and Hanif et al. (2016), respectively of a spinach from soil farming was higher than detected levels in the present work. Likewise, a greater than the level (3.90%) cited by Ranawade et al. (2017) from aquaponics spinach. Similarly, a relatively higher percentage (2.90%) was reported by Kumar et al. (2020) in comparison to the current study. Higher temperature and strong light intensity characteristics features of the summer season enhances sugar synthesis in plants (Lee and Kader, 2000; Caruso et al., 2011). However, not in support with the published research by Ferreyra et al. (2007), they detected that lower temperature which is linked to the winter period promotes sugar production in the alpine strawberry grown in a greenhouse. In this study, the TCA levels of the experimental plant materials were affected by the seasonal differences.

3.5. Soluble protein

The results of the statistical evaluation conducted for the soluble protein (SPR) content (Table 5) indicated no statistically significant differences (P>0.05) between the SPR values of the RCH on a dry matter basis in spring and autumn, and between the values of the RTO in winter and summer. However, there were statistically significant differences (P<0.05) between other seasonal comparison of the values of above samples (RTO and RCH). In addition, a statistically significant differences (P<0.05) existed between all seasonal comparison of values of the GSP and GLE plant samples (Table 5).

Table 5. Seasonal differences in the soluble protein

Seasons	Soluble protein (%)			
	Plant materials (n = 3)			
	RCH, dw	RTO, dw	GSP, dw	GLE, dw
Winter	0.29±0.02^{b}	0.28±0.03^{a}	0.34±0.01^{d}	025±0.01^{c}
Spring	0.24±0.01^{c}	0.23±0.01^{b}	0.79±0.01^{b}	0.30±0.01^{b}
Summer	0.30±0.03^{a}	0.29±0.03^{a}	0.83±0.00^{a}	0.35±0.03^{a}
Autumn	0.26±0.03^{c}	0.22±0.06^{c}	0.68±0.01^{c}	0.22±0.01^{d}

dw = dry weight, RCH = red chili fruit, RTO = red tomato fruit, GSP = green spinach leaf, GLE = green lettuce leaf, n = number of repeats of each experimental sample. The results were expressed as mean±SD. Values with different superscript letters between seasons in a column are significantly (P<0.05) different between seasons.

In this experiment, the highest SPR level for the RCH fruit, RTO fruit, GSP leaf, and GLE leaf was detected in the summer season (Table 5). The GSP leaf showed the highest percentage of SPR among the experimental plant samples.

There were no reports of the effect of seasonal variations on the SPR values of the investigated plant materials from the aquaponics farming. However, Ananthan et al. (2014) reported the SPR values between 0.91±0.02 to 1.98±0.10% from six (6) different cultivars of the red chilies obtained from local markets. Values obtained from the above report were higher than the amount detected in the present research. Hanif et al. (2006) reported a higher soluble protein from tomato fruit (0.9±0.06%) and lettuce (1.2±0.00%) in comparison with obtained amounts in this study. The percentage SPR observed from the GSP leaf in this finding was lower than values of 1.45±0.03%, 2.00%, and 2.70% reported by Barman et al. (2015), Kumar et al. (2020), and Ranawade et al. (2017), respectively. Variation in the SPR levels in the investigated plants in comparison to the above findings might be due to cultivar differences and or employed analytical methods. In the current research work, seasonal differences have induced changes in the level of SPR of the RCH, RTO,GSP, and GLE vegetable plants.

4. Conclusion

This study determined the impacts of seasonal variations on proximate nutritional makers of some vegetable plants derived from the aquaponics cultivation. The total moisture (TMO) content (fresh weight basis); the crude ash (CAS), crude fibre (CFI), total carbohydrate (TCA), and soluble protein (SPR) values (dry weight basis) of the red chili (RCH) fruit, red tomato (RTO) fruit, green spinach (GSP) leaf, and green lettuce (GLE) leaf were significantly ($P<0.05$) different among the comparative seasons. The highest CAS, CFI, TCA, and SPR contents of the RCH, RTO, GSP, GLE plants materials were detected in the summer period. However, the TMO content of the RCH, RTO, GSP, and GLE was detected significant ($P<0.05$) in the winter period. Therefore, the findings of this research indicated that aquaponics food farming and harvesting in the warmer periods could significantly increases the nutritional value composition in plants.

Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

The author carried out the methodology, investigation, conceptualization, data analysis, and curation. The author also write, review, edit, and validate the original draft of the research manuscript.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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References

Adeyeye. I. E. (2005). Trace metals in soils and plants from Fadiman farms in Ekiti state, Nigeria. *Bulletin of the Chemical Society of Ethiopia, 19*(1), 23–33. doi.org/10.4314/bcse.v19i1.21106

Albalasmeh, A. A., Berhe, A. A., & Ghezzehei, T. M. (2013). A new method for rapid determination of carbohydrate and total carbon concentrations using UV spectrophotometry. *Carbohydrate Polymers, 97*, 253–261. doi.org/10.1016/j.carbpol.2013.04.072

Ananthan, R. Subash, K., & Longvah, T. (2014). Assessment of nutrient composition and Capsaicinoid content of some red chilies. *International Conference on Food and Nutrition Technology, 72*, 1–4. doi.org/10.7763/IPCBEE. 2014. V72. 1

AOAC, (2005). Official methods of Analysis of Association of Analytical Chemists. AOAC International, 18th edn. Horwitz, W. Vol. 1 & 2, AOAC International Maryland, USA, pp. 774-784.

Asaolu, S. S., Adefemi, O. S., Oyakilome, I. G., Ajibulu, K. E., & Asaolu, M. F. (2012). Proximate and mineral composition of Nigerian leafy vegetables. *Journal of Food Research, 3*(1), 214–218. doi.org/10.5539/jfr.v1n3p214

Bangash, J. V., Arif, M., Khan, F., Khan, F., Rahman, A. U., & Hussain, I. (2011). Proximate composition, minerals and vitamins content of selected vegetables grown in Peshawar. *Journal of Chemical Society of Pakistan, 33*(1), 118–122.

Barman, P., Sen, M., & Pal, K. M. (2015). Comparative analysis of nutrients of five selected leafy vegetables cultivated in land-filled and normal ground in the city of Kolkata. *International Journal of Current Research, 7*(15), 15958–15962.

Birnin-Yauri, U. A., Yahaya, Y., Bagudo, B. U., & Noma, S. S. (2011). Seasonal variation in nutrient content of some selected vegetables from Wamakko, Sokoto State, Nigeria. *Journal of Soil Science and Environmental Management, 2*(4), 117–125.

Blidariu, F., & Grozea, A. (2011). Increasing the economic efficiency and sustainability of indoor fish farming by means of aquaponics – Review. *Bulletin of Animal Science and Biotechnology, 2*, 44.

Bradford, M. M. (1976). Rapid and sensitive method for the quantitation of microgram quantities of protein utilizing principle of protein-dye binding. *Analytical Biochemistry, 72*, 248–254. doi.org/10.1006/abio.1976.9999

Brook, R. (2017). Home aquaponics system. Top ten benefits of having aquaponics at home. http:www.homeaquaponicssystem.com/basics/top-10-benefits-of-having-aquaponics-at-home (accessed 12 April 2023).

Caruso, G., Villari, G., Melchionna, G., & Conti, S. (2011). Effects of cultural cycles and nutrient solutions on plant growth, yield, and fruit quality of alpine strawberry (*Fragaria vesca* L.) grown in hydroponics. *Scientia Horticulturae*, *129*(3), 479–485. doi.org/10.1016/j.scienta.2011.04.020

Castro, R. S., Azevedo C. M. S. B., & Bezerra-Neto, F. (2006). Increasing cherry tomato yield using fish effluent as irrigation water in Northeast Brazil. *Scientia Horticulturae, 110*, 44–50. doi.org/10.1016/j.scienta.2006.06.006

Castro, M., Teixeira, A., & Fernandez-Nunez, E. (2021). The nutritive value of different Mediterranean browse species used as animal feeds under oak silvo-pastoral systems in Northern Portugal. *Agroforest System, 95*, 269–278.

Dalhatu, T. A., Charles, O. E. V., Cyril, O., & Saidu, M. M. (2018). Comparative evaluation of the phytochemical, proximate and mineral quality of Nigerian Capsicum annum exposed to open and solar drying. *GSC Biological and Pharmaceutical Sciences, 5*(2), 139–144. doi.org/10.30574/gscbps.2018.5.2.0128

Diver, S. (2006). Aquaponics—integration of hydroponics with aquaculture. National Centre for Appropriate Technology (NCAT), Butte, ATTRA publication, 163, pp. 1–28.

DuBois, M., Gilles, K., Hamilton, J., Rebers, P., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry, 28*(3), 350–356. doi.org/10.1038/168167a0

Ferreyra, R. M., Vina, S. Z., Mugridge, A., & Chaves, A. R. (2007). Growth and ripening season effects on antioxidant capacity of strawberry cultivar Selva. *Scientia Horticulturae, 112*, 27–32. doi.org/10.1016/J.SCIENTA.2006.12.001

Flavius, B., & Grozea, A. (2011). Increasing the economic efficiency and sustainability of indoor fish farming by means of aquaponics-review. *Animal Science and Biotechnologies, 2*(44), 1–8.

Hanif, R., Iqbal, Z., Iqbal, M., Hanifa, S., & Raheed, M. (2006). Use of vegetables as nutritional foods: Role in Human Health. *International Journal of Agriculture and Biological Science, 1*(1), 18–21.

Herrera. R. S., Verdecia, D. M., Ramirez, J. L., Garcia, M., & Cruz, A. M. (2017). Secondary metabolites of Leucaena leucocephala. Their relatioship with some climate elements, differents expression of digestibility and primary metabolites. *Cuban Journal of Agricultural Science, 5*(1), 107–116.

Kumar, D., Kumar, S., & Shekhar, C. (2020). Nutritional components in green leafy vegetables: A review. *Journal of Pharmacognosy and Phytochemistry, 9*(5), 2498–2502.

Lee, S. K., & Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biology and Technology, 20*, 207–220. doi.org/10.1533/9780857093622.112

Love, D. C., Fry, J. P., Li, X., Hill, E. S., Genello, L., Semmens, K., & Thompson, R. E. (2015). Commercial aquaponics production and profitability: Findings from an international survey. *Aquaculture, 435*, 67–74. doi.org/10.1016/j.aquaculture.2014.09.023

Mannem, K., Madhu C. H., Asha V. S., & Kumar, V. P. (2012). Quantitative evaluation of carbohydrate levels in green leafy vegetables for home use by UV-visible spectrophotometer. *International Journal of Science and Engineering Research, 3*(8), 1–2.

Mchunu, N., Lagerwall, G., & Senzanje, A. (2018). Aquaponics in South Africa: Results of a national survey. *Aquaculture Reports, 12*, 12–19. doi.org/10.1016/j.aqrep.2018.08.001

Mudzengi, I. P., Murwira, A., Halimani, T., Fritz, H., & Murungweni, C. (2020). Relationships between farmer perceptions and

temporal variation in nutritive value of browse species on savanna rangelands. *African Journal of Range Forest Science, 37*(3), 237–242. doi.org/10.2989/10220119.2020.1779125

Nuri, A., Didah N. F., & Yolanda, S. (2014). Dietary fibre content of water leaf (*Talinum triangularre* (Jacq.) wild) cultivated with organic and conventional fertilization in different seasons. *American Journal of Plant Sciences, 6*(2), 53– 55.

Obirikorang, K. A., Sekey, W., Gyampoh, B. A., Ashiagbor, G., & Asante, W. (2021). Aquaponics for improved food security in Africa: A review. *Frontiers Sustainable Food Systems, 5*, 1–10. doi.org/10.3389/fsufs.2021.705549

Rakocy, J. E., & Hargreaves, J. A. (1993). Integration of vegetable hydroponics with fish culture: In: Techniques for modern aquaculture of American society of agriculture engineers. St. Joseph, USA, pp. 112–136.

Ranawade, P. S., Tidke. S. D., & Kate, A. K. (2017). Comparative cultivation and biochemical analysis of *Spinacia oleraceae* grown in aquaponics, hydroponics and field conditions. *International Journal of Current Microbiology and Applied Sciences, 6*(4), 1007-1013.

Sani, H. A., Tsafe, A. I., Bagudo, B. U., & Itodo, A. U. (2011) Toxic metals uptake by spinach (*Spinacea oleracea*) and lettuce (*Lactuca sativa*) cultivated in Sokoto: A comparative study. *Pakistan Journal of Nutrition, 10*(6), 572–576.

Savidov, N., & Hutchings, E. R. (2005). Fish and plant production in a recirculating aquaponic system: A new approach to sustainable agriculture in Canada. *Acta Horticulturae, 742*, 209–224. doi.org/10.17660/ActaHortic.2007.742.28

Savidov, N. A. (2004). Annual report of greenhouse crops program for 2003/2004. CDC., South, Canada, p. 470.

Sharma, J., Sharma, P., Sharma, B., & Chaudhary, P. (2017). Estimation of proximate composition of selected species of Capsicum (*Capsicum annuum* and *Capsicum chinense*) Grown in India. *International Journal of Pure and Applied Bioscience, 5*(3), 369–372. doi.org/10.18782/2320-7051.5055

Singh, G. A. K., & Sehgal, S. (2001). Nutritional composition of selected green leafy vegetables, herbs, and carrots. *Plant Foods for Human Nutrition, 56*, 359–364. doi.org/10.1023/A:1011873119620

Timmons, M. B., Ebling, J. M., Wheaton, F. W., Summer-felt, S. T., & Vinci B. J. (2002). Recirculating Aquaculture Systems. 2nd end. Northern Regional Aquaculture Center Publication, No. 01-002. Cayuga Aquaculyural Ventures Ithaca, New York. ISBN-13:978-097126461.