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Biochemical and organoleptic evaluation of lettuce varieties grown under DWC technique of aquaponics

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Abstract

Research study was conducted to evaluate biochemical and organoleptic performance of ten lettuce varieties under deep water culture (DWC) technique of aquaponics. Lettuce varieties Lollo Bionda, Butterhead Green, Oak Leaf Red, Lollo Rossa, Batavia, Catalogna Green, Romain Paris Island Cos, Romain Little Gem, Butterhead, and Oak Leaf Green were selected as treatments. Results obtained during course of study shows that highest chlorophyll content reported in Catalogna Green and ascorbic acid in Lollo Rossa. Highest total N content reported in Catalogna Green, P concentration in Butterhead Green while total K content in variety Romain Little Gem. While nutrient uptake was dominated by Catalogna Green. In organoleptic evaluation Romain Paris Island Cos achieved the highest rating for overall acceptability.

Keywords: Lettuce, aquaponics, varieties, DWC

Introduction

Aquaponics is a sustainable, soil-free farming method that integrates aquaculture and hydroponics. Fish waste provides nutrients source for plants, while plants filter and clean the water for reuse (Surnar *et al.*, 2015) [27]. Beneficial bacteria convert ammonia into plant-usable forms, supporting healthy growth. Aquaponics offers efficient water use, space optimization, dual harvests and reduced soil-borne issues (Amrita Sengupta & Banerjee, 2012) [2]. It's particularly useful in areas with limited fertile land. In DWC, roots are submerged in oxygen-rich, nutrient-dense water, fostering growth and yield (Nursyahid *et al.*, 2021) [19]. The stable root environment supports efficient nutrient uptake. This method suits various high value crops like leafy greens and herbs.

Lactuca sativa (2n=18), a leafy vegetable in the Asteraceae family, is a self-pollinating species believed to be originated in ancient Egypt and Iran (Kristkova, 2008) [12]. The name lettuce is derived from the Latin *lactuca*, a reference to the characteristic milky exudate produced upon cutting. The plant flourishes in cool-season conditions, with optimal daytime and nighttime temperatures ranging from 18-25 °C and 10-15 °C, respectively (Ryder, 1998) [24]. Selective breeding has resulted in significant morphological variation in lettuce, encompassing a wide range of colors, shapes and textures. This diversity has facilitated its categorization into distinct types, including butterhead, crisphead, loose-leaf, and romaine along with numerous subtypes and cultivars (Kim *et al.*, 2016; Tudela *et al.*, 2013) [11, 30]. From a nutritional point of view, lettuce is notable for its high content of vitamins (A, C, B-complex), fiber, and minerals such as calcium, iron, and copper. It also contains significant levels of antioxidants and phenolic compounds, which have been shown to possess anti-inflammatory and neuroprotective properties and may help prevent conditions like cancer and heart disease (Kim *et al.*, 2016; Lal *et al.*, 2020) [11, 14]. The growing consumption of lettuce in India reflects advancing consumer preferences and an increased emphasis on health-conscious eating habits (Ogden *et al.*, 2007) [20].

Lettuce is ideal for soilless farming due to its fast growth, shallow roots and efficient nutrient use. It thrives in systems like NFT and deep water culture (Johnson *et al.*, 2000) [10], with reduced pest risks and minimal pesticide needs (Fussy & Papenbrock, 2022) [5]. Its compact form supports space-efficient, year-round production in controlled environments (Gargaro *et al.*, 2023) [6].

Varietal evaluation is essential for optimizing lettuce production in aquaponic systems, specifically when considering plant's biochemical composition. Cultivars vary significantly in their content of important plant nutrients, such as vitamins, minerals, antioxidants, and phenolic compounds. Understanding these varietal differences is crucial for producing crops with enhanced nutritional and medicinal value. Therefore, research into varietal performance is vital for maximizing both the quality and health benefits of lettuce grown in controlled environments like aquaponics.

Materials and Methods

Study was conducted during the Rabi season of 2024 at the Landcraft Agro Aquaponics Unit, Hatkanangale, Kolhapur, Maharashtra, to evaluate the performance of ten lettuce (*Lactuca sativa* L.) varieties under the Deep Water Culture (DWC) technique of aquaponics. Biochemical analysis was performed at central laboratory, Division of Soil Science, RCSM College of Agriculture, Kolhapur.

Lettuce varieties Lollo Bionda, Butterhead Green, Oak Leaf Red, Lollo Rossa, Batavia, Catalogna Green, Romain Paris Island Cos, Romain Little Gem, Butterhead, and Oak Leaf Green were selected as treatments. Biochemical parameters, including nitrogen, phosphorus, potassium, moisture, chlorophyll and ascorbic acid content, were analyzed using standard protocols. Organoleptic evaluation was conducted using a nine-point Hedonic scale by a panel of seven judges. Data were statistically analyzed using Analysis of Variance (ANOVA) as per Panse and Sukhatme (1985) [22] and treatment means were compared using the critical difference at 5% level of significance.

Total nutrient content

Total nitrogen content (%) in plant sample was analysed by Micro Kjeldahl method (Digestion-Distillation) given by Bremner and Mulvaney (1982) [3]. Phosphorus content (%) by vanadomolybdate yellow colour in nitric acid system given by Jackson (1973) [3]. While Potassium content by Flame photometry method (Jackson, 1973) [3].

Nutrient uptake

Nitrogen, phosphorus and potassium uptake (kg/100m²) was calculated using following formula,

$$\text{Nutrient Uptake} = \text{Dry matter yield} \times [\text{Nutrient concentration (\%)/100}]$$

Chlorophyll content at harvest

The total chlorophyll content (mg/g) in lettuce leaves was estimated as per the standard procedure given by Sadashivam and Manickam (1992) [25] in terms of mg per gram. The known sample of lettuce was macerated in Mortar and Pestle by using 80% acetone and the absorbance was measured at 645, 652 and 663 nm using instrument Spectrophotometer.

Ascorbic acid content at harvest

Ascorbic acid content (mg/100 g) in lettuce leaves was determined by using Dichlorophenol-Indophenol dye method. In this method sample of known weight is macerated in mortar and pestle with excess of metaphosphoric acid (1:10 w/v), centrifuged and titrated with 2, 6-dichlorophenol-indophenol dye.

Moisture content

Moisture content (%) in different lettuce varieties was obtained by oven dry method and calculated by formula,

$$\text{Moisture content} = [(\text{Initial weight} - \text{Final weight}) / \text{Initial weight}] \times 100$$

Organoleptic Evaluation

Fresh samples of lettuce were evaluated organoleptically for colour, texture and aroma with the aid of sensory organs. It was performed by a panel of seven judges using nine-point Hedonic scale (Amerine *et al.*, 1965) [1].

Results and Discussion

Total Nitrogen Content

Significantly highest nitrogen concentration (3.97%) was observed in Catalogna Green, followed by Romain Little Gem (3.69%) and Lollo Bionda (3.65%). Whereas, Oak Leaf Green recorded significantly lowest N concentration (2.29%). Variation in nitrogen content could be associated with the genetic makeup and nutrient use efficiency of particular variety.

Significant variation in nitrogen concentration in different varieties in the study is supported by the earlier work of Pooja Dhikale (2022) [23], Grzegorzewska *et al.* (2023) [7], Matysiak *et al.* (2023) [18], Paes *et al.* (2023) [21], Tadevosyan *et al.* (2025) [28].

Total Phosphorus Content

Phosphorus concentration varied significantly with varieties and ranged from 0.20 to 0.42 percent. The maximum phosphorus content (0.42%) was recorded in the plants of Butterhead Green and minimum amount of phosphorus (0.20%) was reported in plants of Batavia.

Similar variation was reported in phosphorus content by Pooja Dhikale (2022) [23], Grzegorzewska *et al.* (2023) [7], Paes *et al.* (2023) [21], and Tadevosyan *et al.* (2025) [28] in lettuce.

Total Potassium Content

Romain Little Gem recorded maximum concentration of potassium (2.18%) while lower concentration was observed in Oak Leaf Green (1.67%).

Potassium concentration recorded in the investigation is in close relation with the results by Pooja Dhikale (2022) [23], Grzegorzewska *et al.* (2023) [7], Matysiak *et al.* (2023) [18], and Tadevosyan *et al.* (2025) [28].

Nitrogen Uptake

Catalogna Green reported significantly highest (0.530 kg) nitrogen uptake. While, lowest nitrogen uptake (0.165 kg) was recorded by Oak Leaf Green. Genetic factors are the primary reason for the variation in nutrient uptake. Each variety has a unique genetic code that determines its root system architecture, affecting its ability to forage for nutrients, and the efficiency of its transporter proteins, which are responsible for absorbing specific nutrients.

Phosphorus Uptake

Catalogna Green recorded significantly highest (0.042 kg) phosphorus uptake, followed by Romain Paris Island cos, and Romain Little Gem (0.037 kg) and significantly lowest uptake (0.015 kg) was recorded by Oak Leaf Green.

Potassium Uptake

Catalogna Green recorded significantly highest potassium uptake (0.276 kg) followed by Romain Paris Island cos (0.250 kg), Romain Little Gem (0.213 kg). While, minimum potassium uptake (0.110 kg) was recorded in variety Butterhead Green.

Table 1: Total N, P and K content of different lettuce varieties under DWC aquaponics

Variety	Total Nitrogen (%)	Total Phosphorus (%)	Total Potassium (%)
Lollo Bionda	3.65	0.30	1.90
Butterhead Green	2.99	0.42	1.74
Oak Leaf Red	2.75	0.28	1.95
Lollo Rossa	2.99	0.32	1.91
Batavia	3.03	0.20	1.83
Catalogna Green	3.97	0.31	2.08
Romain Paris Island cos	3.61	0.29	1.96
Romain Little Gem	3.69	0.38	2.18
Butterhead	2.57	0.40	1.84
Oak Leaf Green	2.29	0.21	1.67
SE _m (±)	0.08	0.01	0.04
CD at 5%	0.23	0.03	0.11
CV (%)	4.35	4.94	3.25

Table 2: Uptake N, P and K by different lettuce varieties under DWC aquaponics

Variety	Nitrogen Uptake (kg/100 m ²)	Phosphorus Uptake (kg/100 m ²)	Potassium Uptake (kg/100 m ²)
Lollo Bionda	0.217	0.018	0.113
Butterhead Green	0.186	0.027	0.110
Oak Leaf Red	0.244	0.025	0.174
Lollo Rossa	0.325	0.034	0.208
Batavia	0.334	0.023	0.200
Catalogna Green	0.530	0.042	0.276
Romain Paris Island cos	0.461	0.037	0.250
Romain Little Gem	0.361	0.037	0.213
Butterhead	0.211	0.033	0.153
Oak Leaf Green	0.165	0.015	0.119
SE _m (±)	0.01	0.001	0.01
CD at 5%	0.02	0.002	0.02
CV (%)	4.51	4.97	4.86

Chlorophyll Content at Harvest

Among the varieties under study, Catalogna Green was significantly highest (2.23 mg/g) in leaf chlorophyll content. Butterhead lettuce recorded significantly lowest leaf chlorophyll content (1.14 mg). Chlorophyll content in plant shows photosynthetic potential of plants of particular variety.

Variation in chlorophyll content is in accordance with Santos *et al.* (2021) ^[26], Thomas *et al.* (2021) ^[29], Pooja Dhikale (2022) ^[23], Idelbe *et al.* (2023) ^[8], Lima *et al.* (2023) ^[15], Matysiak *et al.* (2023) ^[18] and Maia *et al.* (2024) ^[16] in lettuce.

Ascorbic Acid Content at Harvest

Lollo Rossa recorded significantly highest (8.80 mg) ascorbic acid content, followed by Romain Little Gem (7.26 mg), Romain Paris Island cos (6.49 mg) and others.

Results of the experiment were in conformation with results obtained by Mampholo *et al.* (2016) ^[17]; Kumar (2022) ^[17];

Matysiak *et al.* (2023) ^[18]; Paes *et al.* (2023) ^[21]; Tadevosyan *et al.* (2025) ^[28].

Moisture Content

Maximum moisture content (96.06%) was recorded in Butterhead Green, statistically comparable to Romain Little Gem (95.92%), Butterhead (95.65%) and three other varieties whereas, minimum moisture content (93.87%) was observed in plants of Catalogna Green. Variation in moisture content is due to genetic makeup, root structure and water use efficiency of that specific variety.

Similar variations for moisture content of different cultivars were also recorded by Kumar (2022) ^[17] in lettuce and Dalave (2022) ^[4] in dill crop in their experiments.

Table 3: Chlorophyll, Ascorbic Acid and Moisture content of different lettuce varieties

Variety	Chlorophyll Content (mg/g)	Ascorbic Acid Content (mg/100 g)	Moisture (%)
Lollo Bionda	1.78	2.63	95.29
Butterhead Green	1.47	1.87	96.06
Oak Leaf Red	1.48	5.72	94.63
Lollo Rossa	1.35	8.80	93.90
Batavia	1.67	5.32	94.04
Catalogna Green	2.23	4.95	93.87
Romain Paris Island cos	2.11	6.49	94.57
Romain Little Gem	1.92	7.26	95.92
Butterhead	1.14	1.89	95.65
Oak Leaf Green	1.30	5.34	94.06
SE _m (±)	0.03	0.11	0.54
CD at 5%	0.09	0.31	1.60
CV (%)	3.29	3.61	0.99

Table 4: Ratings obtained by lettuce varieties in organoleptic evaluation

Variety	Colour	Aroma	Crispness	Texture	Overall Acceptability
Lollo Bionda	7.00	6.86	7.29	7.00	7.04
Butterhead Green	6.86	6.86	7.43	7.29	7.11
Oak Leaf Red	6.71	6.86	7.00	7.14	6.93
Lollo Rossa	6.57	6.71	6.86	7.00	6.79
Batavia	7.29	7.00	7.43	7.29	7.25
Catalogna Green	7.14	6.71	7.00	7.00	6.96
Romain Paris Is. Cos	7.86	7.29	7.57	7.57	7.57
Romain Little Gem	6.86	6.86	7.00	6.86	6.89
Butterhead	6.71	6.71	7.14	7.14	6.93
Oak Leaf Green	7.14	7.14	7.00	7.00	7.07

Organoleptic Evaluation

Romain Paris Island Cos, Batavia and Butterhead Green exhibited a more pronounced tender texture compared to other varieties. In terms of aroma, Romain Paris Island Cos and Oak Leaf Green stood out with a more fragrant profile than the other treatments. Regarding colour, Batavia and Romain Paris Island Cos were superior to rest. Additionally, Romain Paris Is. Cos, Batavia, and Butterhead Green were noted for their enhanced crunch and crispness. Among all the varieties, Romain Paris Island Cos achieved the highest rating for overall acceptability.

Conclusion

Catalogna Green emerged as a top performer, demonstrating the highest levels of chlorophyll and total nitrogen content and dominating nutrient uptake. This suggests its potential as a highly productive and nutrient-dense crop. However, no single variety excelled in all aspects. While Catalogna Green led in several metrics, Lollo Rossa was notable for its high ascorbic acid content, and Romain Little Gem for its high potassium content. Butterhead Green also showed its strength with the highest phosphorus concentration.

In terms of consumer preference, the study found that Romain Paris Island Cos was the most palatable variety, receiving the highest ratings for overall acceptability.

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