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Composition changes of eggplant fruits (*Solanum melongena* L.) after different cooking treatments

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ABSTRACT
The type of cooking method that retains the optimum amount of nutrient in vegetables and fruits is still necessary to understand its impact. This study deals with the effects of three basic conventional cooking treatments (blanching, boiling and stir-frying) on the micronutrient content of three varieties of (*Solanum melongena* L.) known as short, round and long purple eggplant fruits. Proximate analysis, texture analysis, colour analysis, pH, titratable acidity, total soluble solid and simple sugar analysis were carried out for this purpose of study. The proximate analysis revealed that there was a significant loss of nutrients during cooking treatments, with a high loss for boiling, followed by blanching and stir-frying. Fat content for short variety was dropped from 2.25% in a stir-fry to 0.02% in boil treatment, and protein content was decreased from 1.68% in blanching to 110% in stir-fry treatment. Texture properties and simple sugar content observed a significant change for each treatment, while there were no significant changes observed in colour, pH, titratable acidity and total soluble solid of the samples. Stir-fry is the most suitable cooking method in retaining the optimum amount of nutrient in all the three varieties of eggplant.

INTRODUCTION

Consumer demands have recently shifted to include not just producing food to narrow the hunger gap, but also eating healthy food to improve people's physical and mental health and avoid the spread of foodborne infections (Gupta et al., 2022). Grown for its edible fruit, eggplant (*Solanum melongena* L.), often known as aubergine, is a species of nightshade. The plant's several cultivars provide fruit that varies in size, shape, and color—most commonly, purple (Gürbüz et al., 2018). Though produced in India and other parts of Asia, including Malaysia, eggplant is grown in a considerably wider range of forms, sizes, and colors. It is stretched to 12–25 cm long (4 1⁄2 to 9 in) and 6–9 cm broad (2 to 4 in) with a dark purple skin (Aworinde & Ogundele, 2015). One of the top ten vegetables with the highest antioxidant activity is eggplant, which is distinguished by its high concentration of phenolic compounds with antioxidant qualities.

Furthermore, eggplant is known for having a high concentration of phenolic acids, particularly chlorogenic acid, in the flesh and for having flavonoids in the peel that contain significant amounts of the anthocyanin nasunin (Niño-Medina et al., 2017). In order to enhance digestion and metabolism in the human digestive system, the majority of foods need to be processed. However, many of the physical characteristics of food—including appearance, sensory qualities, and chemical composition—are changed during preparation (Salamatullah et al., 2021). It is typically eaten after being grilled, fried, or brought to a boil in water (Naeem & Ugur, 2019). In general, of nutrition, eggplant is known to have very low in calories as it consists of high-water content about 95% and only 25% of calories per serving. Yet, eggplant is an important source of fiber, vitamins and minerals (Caguiat & Hautea, 2014; Naeem & Ugur, 2019), and It has been linked to decreased blood pressure, a decreased prevalence of obesity, increased satiety, and a decreased risk of constipation, hypercholesterolemia, colon cancer, and gastrointestinal disorders (Yarmohammadi et al., 2021).

Because of their health benefits, people who are health-conscious will frequently include vegetables and fruits in their meals, with the variety of vegetables and cooking methods varying to enhance the taste. As a result, it's critical to assess the influence of cooking methods that preserve the most nutrients as well as the functional characteristics of vegetables and fruits (Salamatullah et al., 2021). In this study, it is focus on three varieties of purple eggplant based on its shape, short, round and long. The influence of three distinct cooking methods (blanching, boiling, and stir-frying) on the physicochemical, and nutritional makeup of eggplants were investigated.

MATERIAL AND METHODS

Materials and sample collection

Three varieties of fresh ripen purple eggplant fruits from family of Solanum melongena L.; short (18 cm x 3 cm), round (6 cm x 6 cm) and long (30 cm x 2.5 cm) long and width respectively were purchased directly from the local market in Selangor, Malaysia, were brought right away to the lab, where they were kept until later usage at 4 ± 1 °C. The analytical grade chemicals utilized in this investigation were all acquired from Sigma-Aldrich Co. (St. Louis, MO, USA).

Sample preparation

To make sure that all impurities were gone, all fresh veggies were rinsed with tap water two or three times, then again with distilled water. After that, each one was prepared independently utilizing standard home procedures. Hand removal of inedible portions was accomplished with a sharp knife. Every sample was divided into its edible portion, which was then drained over a stainless-steel sieve after being cleaned once more with distilled water. After the veggies' edible components were finely cut, each sample was separated into four pieces. The remaining sections were prepared and cooked as follows: boiling, blanching, or stir-frying. One portion was analyzed as a fresh sample.

Cooking methods

Three distinct techniques were used to cook the eggplant samples. About 100 g of veggies were used in the blanching process, which involved submerging them in boiling water at 100 °C for one to three minutes. After draining the samples on a steel strainer until they were cold, they were weighed. Next, 500 mL of distilled water were added to a container, covered with a lid, and heated to boiling temperature to perform the boiling procedure. Boiling water (100 °C) was used to cook each vegetable sample (100 g) until it was soft, which took 3-5 minutes.

Proximate analysis

The AOAC (2006) standard approach was used to determine the total moisture, ash, crude fat, crude fiber, crude protein, and carbohydrate contents in three different types of eggplants that were tested.

Texture analysis

Using a Texture Analyzer (model TA. XT Plus, Stable Micro Systems, UK), the texture profile analysis (TPA) method was used to determine the texture qualities of eggplant slices. Using the Probe: P/36R; 36mm Dia Aluminium Radiused AACC, one compression cycle between parallel plates was utilized to analyze the textural profile of cylindrical samples (diameter 5 cm, height 1 cm), with a 5-second interval between cycles. The following were the parameters that were applied: Test speed of 0.5 mm s^{-1} and force load cell of 30 kg (Guiné & Barroca, 2012; Nayak et al., 2007).

Colour analysis

The samples' color was evaluated using a Minolta Chroma Meter CR-410 (Konica Minolta, Inc., Japan). The instrumental color data were expressed in terms of the three-dimensional CIE L*, a*, and b* coordinates, which describe color. L* (dark–light), a* (redness–green), and b* (yellowness–blueness) are these coordinates. Eggplant slices were placed in an inadequate container. Two color measurements were made (Urun et al., 2015).

pH, titratable acidity and total soluble solid analysis

The pH, titratable acidity and total soluble solid in three different varieties of eggplants studied were estimated by the standard procedure of the (AOAC, 2006).

Simple sugar analysis

The HPLC method by Rosa-Martínez et al., (2021) was used to determine the sugars in eggplant fruits using Purospher STAR NH2 (5µm) LiChroCART 250-4.6 HPLC cartridge. The eluent used was acetonitrile and distilled water (80/20, v/v). The sugar standard use is glucose, fructose and sucrose in the concentration range 1 to 5% (w/v). Sugars in the samples were quantified by comparing the peak areas of samples with the standards of fructose, glucose and sucrose. A calibration curves were obtained for each sugar. Fifty gram of eggplant fruits material was blended with 100 ml of distilled water for 2 minutes. Then, it was boiled at 100 °C for about 5 minutes. The mixture was filtered through cotton wool into a beaker, and filtered again using 0.45 µm Eppendorf membrane filters, by using a syringe into Eppendorf tube 2 ml. 10 µl volumes was injected into HPLC infrared detector.

Statistical analysis

The current study's mean values ± SD were used to illustrate the results. After using a one-way analysis of variance (ANOVA), the Tukey test was used to identify significant differences between mean values at a significance threshold of $p<0.05$. MINITAB software, version 16, was used to do statistical analysis.

RESULTS AND DISSCUSION

The chemical composition and the texture of eggplant fruits (*Solanum melongena* L.) make them attractive to human consumption all over the world. In addition of that, eggplant fruits are known to have a quite high in nutritive value, and somehow have a reasonable nutritional value that can be compared with the tomato make them as a good vegetable (Kalloo, 1993). The chemical composition of the eggplant fruits was discovered to be influenced by the physical traits of the fruits, including color and shape, the presence of spines on the calyx, the color of the foliage, and the treatments used (Dighe, 1995). Three different varieties of purple eggplant fruits were used in this study, known as short, round, and long size variety and treatment used were blanched, boiled, and stir-fried. Chemical composition for short variety of eggplants is shown in Figure 1a-c.

From the Figure 1a, the short eggplant fruits are found to have high in moisture, minerals, crude protein and crude fiber content. Besides that, there are significant losses of nutrients after treated. The losses are high in crude protein, crude fat, and crude fiber. Round variety of purple eggplant fruits rich with crude protein and carbohydrate compared with other two eggplant fruits Figure 1b. Once been treated, the chemical composition shows significant difference of losses. There are also slightly losses of ash and crude fat content with different cooking treatments with high losses of crude protein and crude fiber. This variety of eggplant has a hard and full structure of flesh fruits gave them higher starch content.

For long variety of fruits, they are high in moisture, crude fiber and crude protein content Figure 1c. They also did show significant difference in composition after introduce with different treatment. According to Saha et al., (2023), long-fruited cultivars have higher average concentrations of dry matter, amino protein, total water-soluble sugars, free reducing sugars, and compounds called anthocyanins and phenols, which are responsible for the fruit's deep purple skin color.

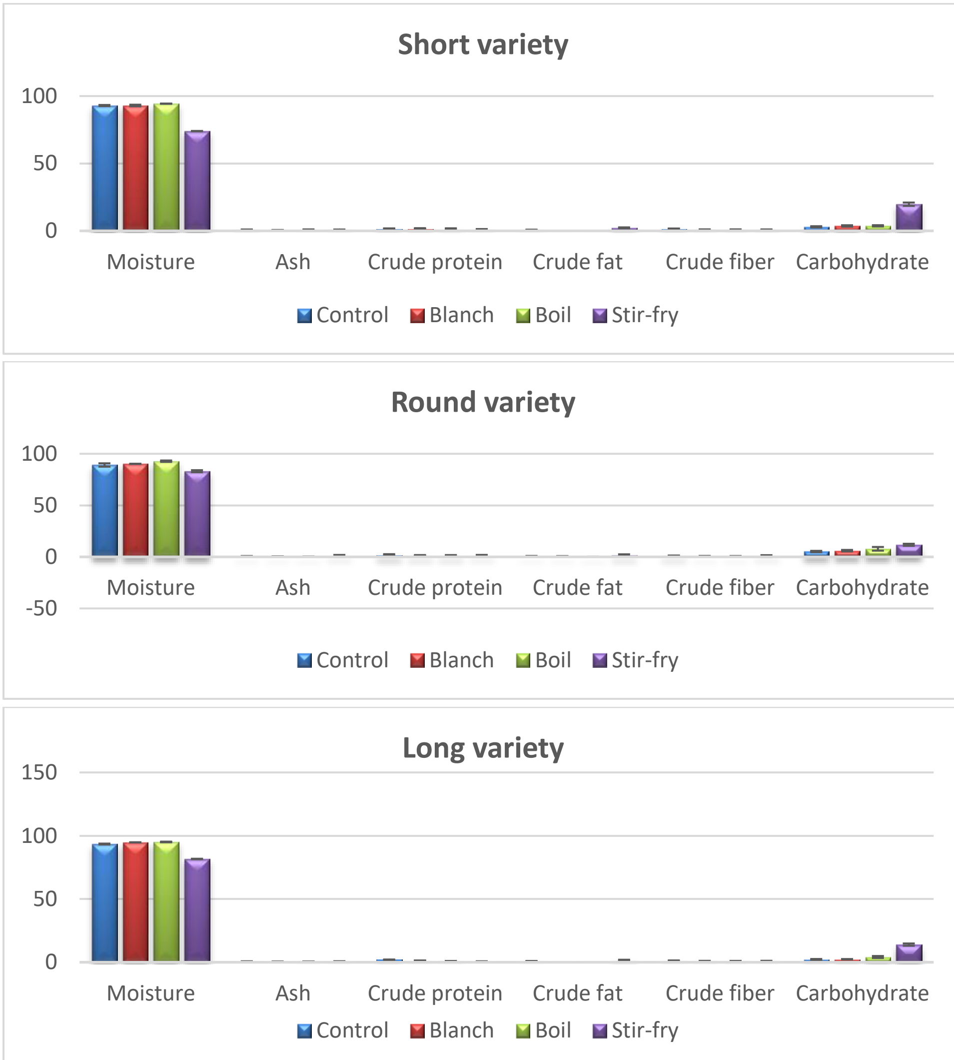

Figure 1a-c: Chemical composition for short, round, and long variety of purple eggplant fruits.

Moisture content in the three varieties of eggplant increase when they were undergoes blanching and boiling treatment, but decreases the moisture content in stir-frying. Long variety of eggplant contains higher moisture follow by short and round eggplant. In comparable with (Nisha et al., 2009), moisture content in purple coloured big size, purple coloured moderate size and purple coloured small size are 93.28 ± 1.2, 91.48 ± 0.80% and 89.67 ± 0.63% respectively. Blanching, boiling and stir-frying treatments as Somsub et al., (2008) reported in tomato show the same trend as in this study.

Ash content is a measure of the total amount of minerals present within a food. Eggplant is known rich with minerals content; potassium, chlorine, magnesium and calcium are present in high concentrations (Saeed et al., 2018; Saha et al., 2023). Minerals are highest in the green and lowest in the purple cultivars (Saeed et al., 2018). In this case, ash content in short variety of eggplant is higher than round and long eggplant, while introduction with different treatments did slightly decrease the ash content in three varieties of eggplant.

Round and long varieties have the same percent of crude protein, and short variety has slightly low percent of crude protein compared with the others two. When applied with different treatments, they did shows decreasing pattern of number of crude proteins in eggplant. This is might be because of the temperature/time for the treatments used still cannot breakdown the protein structure. The skin and flesh tissues of a number of fruits and vegetables, including potatoes, tomatoes, onions, and apples, are frequently distinguished by their unique metabolite composition or content (Stushnoff et al., 2010). This is likewise the case for eggplant, whose skin and fruit flesh have different phenylpropanoid profiles, suggesting that the degree of accumulation is closely controlled (Mennella et al., 2010).

In term of crude fat, the three varieties of eggplants did show the same pattern as they are decreasing with blanched and boiled treatments, however increased of crude fat content when used stir-fried, due to oil used during process. The results obtained indicated that different types of eggplant have different fat content, which was in agreement with the previous study by done (Nisha et al., 2009).

Most of the vegetable are rich with fiber, so as in eggplant. It is able to prolong the feeling of fullness because the bulking properties of dietary fiber can affect satiation and satiety (Burton-Freeman, 2000). From the data obtained, content of crude fiber in short variety of eggplant is found somehow higher than the other two varieties. They might be from the structure of the fruits with roughage surface. Plants often have an exterior cell wall made of polysaccharides and cellulose, which maintains the form and development direction of the cell while offering stiffness and mechanical support. Additionally, the cell wall stops the cell from expanding when water enters it (Cosgrove, 2023). Meanwhile, the trend also same for the three varieties as they are decrease in crude fiber content when they are been treated (blanched, boiled, and stir-fried).

Carbohydrate is the largest nutrient component in eggplant. Carbs, which include both simple sugars and complex carbs, make up the majority of the material that makes up vegetables (Hartvig, 2023). From the study, it is showing the trend increasing with different treatments applied; blanched, boiled, and stir-fried. The highest carbohydrate content in round eggplant, followed with short and long varieties of eggplant. Results of the present investigation are similar to the carbohydrate content obtained by (Nisha et al., 2009).

In short, the three varieties of eggplant fruits show significant loss of nutrients with introducing of cooking treatments with high loss for boiling, follow by blanching and stir-frying. This might be due to the thermal treatments and times induce from cooking process, besides the cooking process itself. As for boiling process, with high temperature and long times cooking cause high amount of nutrients loss. In addition, most of the nutrients are water soluble; so, treatments with water will cost high loss of nutrients.

There are five parameters that been looking at which is hardness, springiness, cohesiveness, gumminess, and chewiness. The values of control and treated samples were measured for determining textural properties of eggplant samples. Textural properties of eggplant samples were given in Table 1.

Table 1: Textural properties of eggplant fruits

Samples	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
(S)Control	15,064.00 ± 21.00[a]	0.67 ± 0.01[a]	0.62 ± 0.05[a]	8809.90 ± 16.20[a]	538.51 ± 0.74[a]
Blanch	2956.00 ± 12.00[b]	0.55 ± 0.03[a]	0.30 ± 0.03[b]	881.90 ± 3.00[b]	484.78 ± 0.49[b]
Boil	1560.00 ± 18.00[c]	0.73 ± 0.03[a]	0.38 ± 0.00[b]	482.70 ± 14.30[d]	344.42 ± 0.84[d]
Stir-fry	1623.00 ± 30.00[c]	0.64 ± 0.10[a]	0.38 ± 0.00[b]	748.60 ± 4.00[c]	460.21 ± 0.34[c]
(R)Control	2207.70 ±17.20[a]	0.76 ± 0.04[a]	0.62 ± 0.03[a]	400.54 ± 0.99[d]	299.68 ± 0.50[d]
Blanch	1614.90 ± 28.50[b]	0.69 ± 0.07[a]	0.39 ± 0.00[b]	489.52 ± 2.83[c]	326.11 ± 1.46[c]
Boil	1283.30 ± 40.70[c]	0.78 ± 0.14[a]	0.41 ± 0.00[b]	909.49 ± 2.16[a]	668.68 ± 4.77[a]
Stir-fry	1497.90 ± 57.70[b]	0.73 ± 0.02[a]	0.38 ± 0.02[b]	551.17 ± 3.37[b]	404.97 ± 0.16[b]
(L)Control	1709.50 ± 78.50[a]	0.73 ± 0.12[a]	0.61 ± 0.03[a]	773.06 ± 0.55[a]	451.23 ± 0.67[a]
Blanch	1659.20 ± 72.60[a]	0.63 ± 0.08[a]	0.61 ± 0.03[b]	644.89 ± 68.00[a]	374.41 ± 6.32[b]
Boil	1028.20 ± 25.70[c]	0.61 ± 0.02[a]	0.61 ± 0.03[b]	369.44 ± 3.68[b]	220.18 ± 1.67[c]
Stir-fry	1289.10 ± 31.70[b]	0.68 ± 0.03[a]	0.61 ± 0.03[b]	692.62 ± 6.23[a]	463.53 ± 2.55[a]

Values are expressed as mean ± standard deviation of two replicates measurement. Values are denoted significant different by one-way ANOVA at the level $p < 0.05$. Notes: (S-short variety; R-round variety; L-long variety).

As a result of statistical examination of textural properties of treated samples, it was found that there are significant in terms of hardness, cohesiveness, gumminess and chewiness values of samples *($p<0.05$)*. However, it was determined that there was no significant difference between the springiness values of eggplant samples *($p>0.05$)*. From the data collected, there are a huge different on texture in term of hardness, cohesiveness and gumminess while, slightly different in chewiness of the samples after been treated. Boiling gave the high impact on texture follow by blanching and stir-frying.

The composition of the plant cell walls, the central lamella that keeps the cells together, and the turgor pressure of the majority of plant materials are what determine their texture because they are surrounded by semi-permeable membranes and contain a sizable amount of water and other liquid-soluble elements. A food's textural features are a collection of physical attributes that result from its structural components, according to Bourne (Yang et al., 2020). When it comes to texture, solid or semi-solid meals are generally employed; however, viscoelastic foods—which show viscosity (flow)—and perfect solids—which only show elasticity (deformation)—are used for fruits and vegetables.

In this project *L*, a*, b** values of raw and treated eggplant samples were measured during determining colour parameters of samples. Colour parameters of samples were showed in Table 2.

Table 2: Colour parameters of eggplant fruits

Samples	*L**	*a**	*b**
(S)Control	29.60 ± 0.01[a]	0.70 ± 0.00[a]	-1.02 ± 0.00[a]
Blanch	29.60 ± 0.00[a]	0.71 ± 0.01[a]	-1.02 ± 0.00[a]
Boil	29.59 ± 0.00[a]	0.67 ± 0.05[a]	-1.05 ± 0.01[b]
Stir-fry	29.57 ± 0.05[a]	0.70 ± 0.01[a]	-1.03 ± 0.00[a]
(R)Control	29.57 ± 0.04[a]	0.70 ± 0.02[a]	-1.04 ± 0.01[a]
Blanch	29.59 ± 0.01[a]	0.71 ± 0.01[a]	-1.02 ± 0.01[a]
Boil	29.59 ± 0.01[a]	0.68 ± 0.03[a]	-1.02 ± 0.01[a]
Stir-fry	29.59 ± 0.01[a]	0.70 ± 0.01[a]	-1.03 ± 0.01[a]
(L)Control	29.59 ± 0.01[a]	0.73 ± 0.01[a]	-1.05 ± 0.01[a]
Blanch	29.60 ± 0.01[a]	0.67 ± 0.02[a]	-1.03 ± 0.01[a]
Boil	29.60 ± 0.01[a]	0.70 ± 0.01[a]	-1.03 ± 0.01[a]
Stir-fry	29.60 ± 0.01[a]	0.68 ± 0.02[a]	-1.04 ± 0.01[a]

Values are expressed as mean ± standard deviation of two replicates measurement. Values are denoted significant different by one-way ANOVA at the level **p <0.05**.

From the result of statistical examination, it found that treatment did not affect to *L**, *a**, and *b** values of eggplant samples *(p<0.05)*. So, it was concluded that treatment process had no significant effect on colour parameters of samples. Tontul & Topuz, (2017) suggested that increasing the temperature will decrease the colour lightness and raised the saturation in the samples. *L*, a*, b** coordinates, which define the colour in a three-dimensional space: *L** (dark–light), *a** (redness–green) and *b** (yellowness–blueness) with positive values *+a* equivalent with the redness colour parameter and *–a* is more to green coordinates, +b is yellowish and *–b* is bluish, last not least *+L* is darker coordinate and *–L* is lighter.

From the results, the colour of samples is categorising as darker colour, redness and bluish. Eggplant fruits are rich with antioxidant source known as anthocyanins compound. The primary pigments of anthocyanins are red and blue, but anthocyanins are sensitive to pH and heat, that might explain on slight changes upon treatments. In addition, enzymatic and non-enzymatic browning reactions may result in the formation of water-soluble brown, grey, and black coloured pigments.

The Figure 2 lists the results of pH, acidity (%), and total soluble solids (Brix°) of slices of control and after treated eggplant. Comparing the results between the samples of control and treated samples, it was observed similar results for pH and titratable acidity and the soluble solids content for the sample. The values of titratable acidity, soluble solids and pH of eggplants had almost no changes after the treated, compared to control.

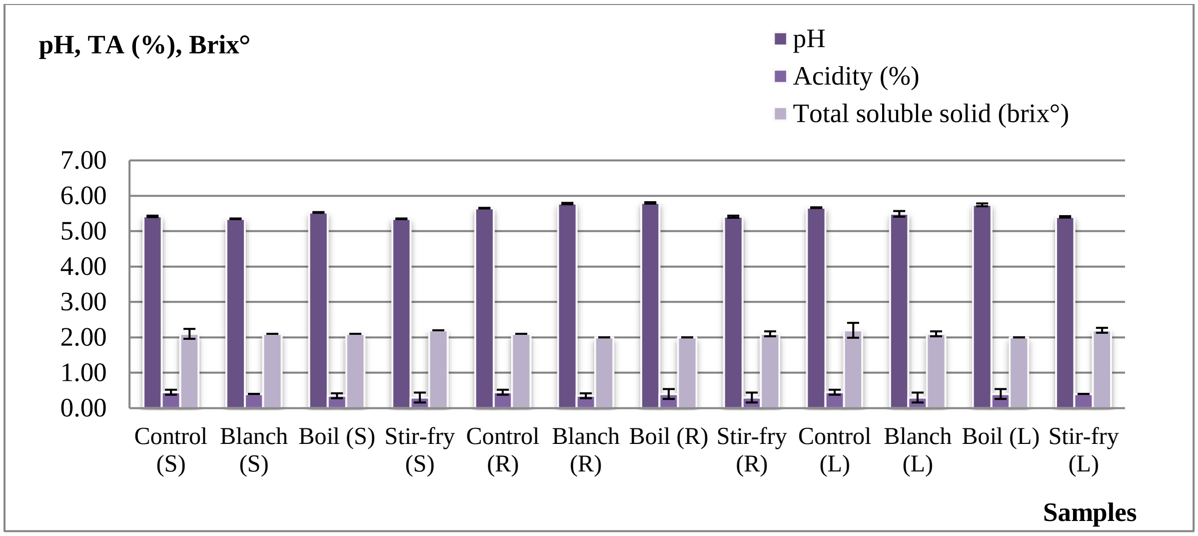

Figure 2: pH, acidity (%), and total soluble solids (°Brix) of slices eggplant

Figure 2 shows linear trend line and from the data, there are significant different of pH value comparing between treatment for the three varieties, but no significant different for acidity (%), and total soluble solids (°Brix). Other study done by Osidacz & Ambrosio-Ugri, (2013), state that, pH value for fresh eggplant sample is 5.47 and 4.66 after dried. While, titratable acidity (%) is 1.98 in fresh sample and increase up to 2.19 when treated. For total soluble solid (°Brix) content, 4.0 for fresh sample and reduce to 3.6 when treated. We can say moisture content in the samples did effect on pH, titratable acidity and total soluble solid.

The capacity of food to be preserved is dependent on its pH level. A pH in the range of 3 to 6 is ideal for the growth of mold and yeast. The findings indicate that the pH of the sample decreased after it was stir-fried and blanched but somewhat increased when it was boiled. Ergezer & Gokce, (2011) suggests that rises in pH may be associated with both the release of calcium and magnesium ions from proteins as well as a decrease in the amount of accessible carboxylic groups in proteins. Moreover, the pH values range below 6 which expose them to microbial activity. It was suggested to not keep the eggplant dishes for a long time after cooked.

When fruit goes through the maturing process, its acidity level decreases, and the ratio of sugar to acidity determines whether the fruit has a mild, balanced, or sour flavor when compared to a fresh sample. Furthermore, depending on the cooking process, cooking can alter the acidity of eggplant in both favorable and bad ways. In this investigation, the acidity of the eggplant was reduced following treatment, and no discernible differences were found. The correlation coefficient was assessed in order to identify any possible associations between the acidity of eggplant extracts and their pH value. In fact, there was only a slight positive connection ($r = 0.31$) discovered between the two measures. The presence of glycoalkaloids also said is responsible for bitter taste in eggplant fruits. This value of titratable acidity could be caused by the changes of the concentration of protonated, lower acidity constants, organic acids content (Pacifico et al., 2021). Meanwhile, no significant different found in total soluble solid content of samples. From reading, no results have been reported on the effect of cooking on the total soluble solid of eggplant.

Sugar analysis. The simple sugars content in samples are shown in Figure 3a-c.

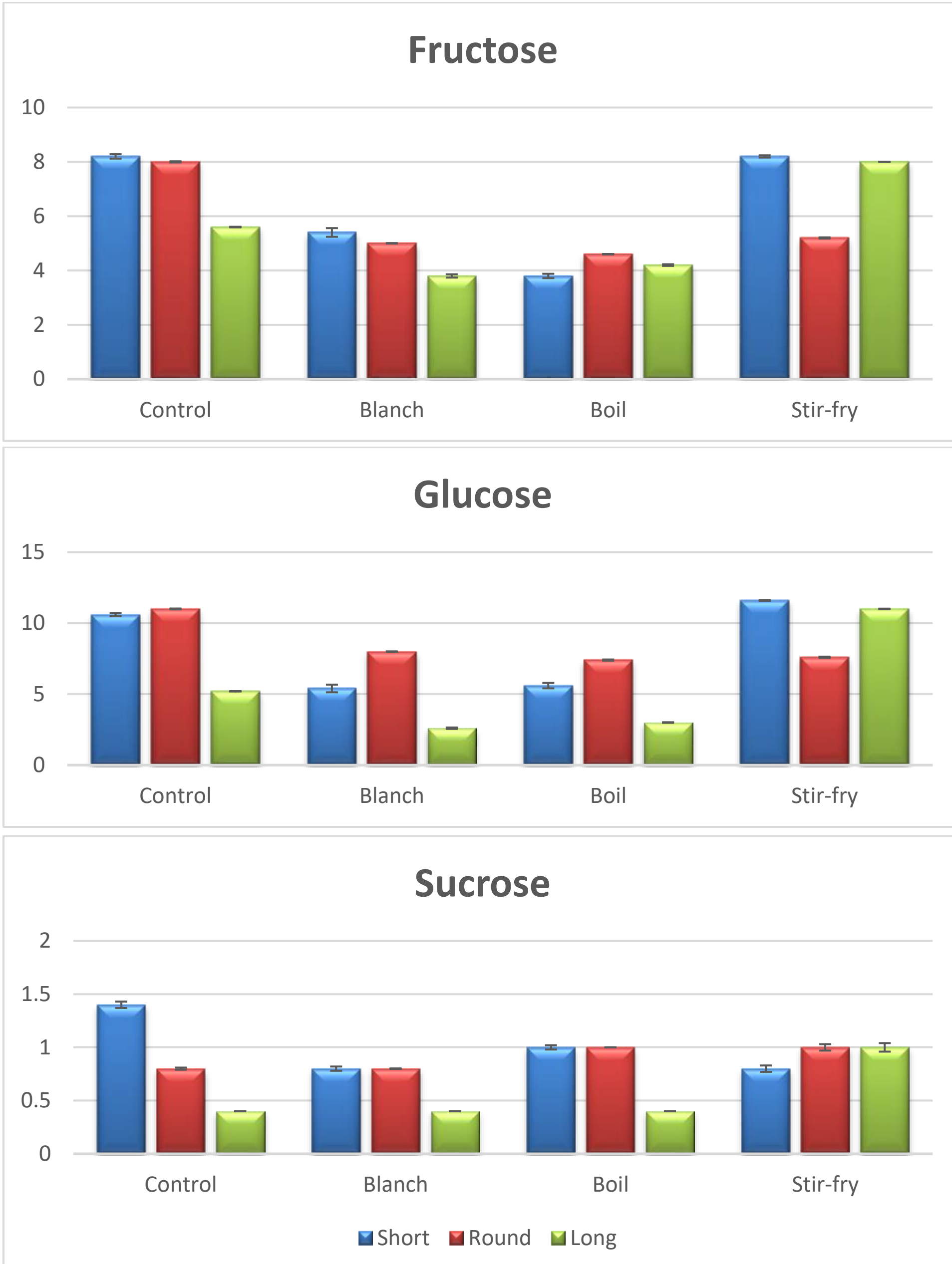

Figure 3a-c: Fructose, Glucose, and Sucrose content in eggplant samples

Even though sugar is a significant chemical molecule with nutritional significance, little information was available regarding how cooking methods affected the amount of simple sugar in eggplant. The sugar level of the blanched and boiled eggplant dramatically dropped ($P < 0.05$) after cooking, while it remained slightly high after stir-frying. Fresh eggplant had the highest value found. Glucose content is higher in eggplant follow with fructose and sucrose. Besides that, data shows short variety has more sugar content than round and long variety, but round variety has higher glucose content.

This decrease can be explained by the fact that sugars are been diluted during blanching and boiling process, and become concentrated when frying. The storage form of sugar in plants is starch and the starch become soluble in water when heated. High starch content somehow indicates high sugar content. In an attempt to understand the relationship between these two, the correlation coefficient was evaluated and found out a high positive correlation between the two (r = 0.62).

In addition, the Maillard reaction could contribute to the result. In general, the most important factors to consider are pH and water activity, as well as temperature and duration, which are dependent on the cooking environment [30]. Two such responses include the Maillard reaction, which is the outcome of reactions between reducing sugars and proteins and their derivatives, and caramelization browning, which is caused by sugar-sugar reactions when heated to high temperatures (Namlı, 2019).

CONCLUSION

The three varieties of purple eggplant fruits; short, round and long variety used in this study were found in general to have high in moisture and crude fiber content. Short variety was found high in crude fiber, round variety high with crude protein and carbohydrate meanwhile long variety rich with moisture and crude protein. The effects of different cooking treatment on nutritional composition of the three varieties of purple eggplant fruits. Blanch; boil and stir-fry gave significant loss of nutrients, texture, pH and sugar content, meanwhile no significant on colour, acidity, and total soluble solids on eggplant fruits. Generally, it was found that stir-frying is the appropriate cooking method that retains the optimum amount of nutrients in eggplant samples. Further study on various cooking treatments is required to observe the parameter that might contribute to the results obtained in addition to the antioxidant content (Polyphenols, vitamin C, Anthocyanins) and evaluate the effects of maturity stage on nutrients.

CONFLICT OF INTEREST

The authors declare that the study was conducted without a potential conflict of interest.

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