BioScientific Review (BSR)
Volume 5 Issue 2, 2023
ISSN$_{(P)}$: 2663-4198 ISSN$_{(E)}$: 2663-4201
Homepage: https://journals.umt.edu.pk/index.php/bsr

Article QR

Title:	**Nutritional Quality and Yield Performance of Plum (Prunus domestica) Varieties Grown in Punjab, Pakistan**
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DOI:	https://doi.org/10.32350/bsr.52.06
History:	Received: August 29, 2022, Revised: January 14, 2023, Accepted: March 4, 2023, Published: June 28, 2023
Citation:	Ahmad N, Ahmad S, Tariq I, et al. Nutritional quality and yield performance of Plum (Prunus domestica) varieties grown in Punjab, Pakistan. *BioSci Rev*. 2023;5(2):56–67. https://doi.org/10.32350/bsr.52.06
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Conflict of Interest:	Author(s) declared no conflict of interest

A publication of
The Department of Life Sciences, School of Science
University of Management and Technology, Lahore, Pakistan

Nutritional Quality and Yield Performance of Plum (*Prunus domestica*) Varieties Grown in Punjab, Pakistan

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ABSTRACT

Pakistan is ranked 17th in the world for plum production, with a total output of 67,000 tonnes. In terms of area and production, plum (*Prunus domestica*) is Pakistan's second largest stone fruit, after peach. Plum (*Prunus domestica L.*) is a temperate zone fruit crop, made up of different varieties. This study was carried out to evaluate the nutritional quality and yield performance of five different plum varieties (Methley, Shakar Prune, Santa Rosa, Hersminar, and Red Beaut) grown in the Punjab province of Pakistan. Plum samples were collected from the Horticultural Research Station, Nowshera (Soon Valley), Pakistan during May 2021 and analyzed for fruit yield and nutritional quality parameters. The maximum fruit fresh weight (52.9g) was recorded in Red Beaut and the lowest fresh weight (12.4 g) in Methley. The cultivar with the highest nutritional value was Shakar Prune with 16.4% of total soluble solids (TSS) and 12.2% of total sugars content, whereas the lowest nutritional value was recorded in Herisminar with total soluble solids (TSS) and total sugars content of 14.8% and 10.0%, respectively. All varieties showed significant variation in terms of fresh weight, total soluble solids (TSS), and total sugars. The results showed the yield performance and nutritional quality of different plum varieties, with Red Beaut and Shakarprune cultivars highlighted as the best. The study concluded that yield performance and nutritional quality depend strongly on the respective plum variety.

Keywords: Herisminar, plum fruit, Red Beaut, Santa Rosa, Shakar Prune, Total Soluble Solids (TSS), total sugars

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1. INTRODUCTION

The importance of fruits cannot be denied since they are essential to fulfil the nutritional needs of the body and are also known for being delicious. Hence, they enjoy a high demand in the market which underpins their cultivation and production on a large scale. Plum (*Prunus domestica*) is one such fruit that is packed with nutrients. The small fruit has a tasty flesh and an outer firm skin. The color of the outer skin may vary considerably from yellow or dark red to dark purple or black [1]. The fruit has a single stone. It is a delicious fruit eaten all over the world.

With so many existing varieties of plum, it is no surprise that these varieties have varied histories and origins all across the globe. The cultivation of plums has been practiced since ancient times, may be longer than any other fruit except apple [2]. The earliest known evidence about plums dates back to 470 BC and indicates that this fruit originated in China [3]. European plums are believed to have been first spotted around two thousand years ago in the region surrounding Eastern Europe and Western Asia. There were 300 varieties of European plums described in ancient Rome and pilgrims brought this fruit to the United States in the 17th century [3]. It was first introduced in Japan 200-400 years ago [2] and then spread around the globe. Plums may have been one of the earliest fruits grown by human beings. Today, this fruit is grown in every region with a temperate climate. European plum (Prunusdomestica) was originally grown in Europe, followed by the American plum (*Prunus americana*) in America, the cherry plum (Prunuscerasifera) in South Asia, and the Damson plum (Prunussalicina) in Western Asia [4].

In terms of cultivated area and production, plum (*Prunus domestica*) is Pakistan's second-largest stone fruit, after peach. Plum (*Prunus domestica* L.) is a temperate zone fruit crop, which belongs to the genus *Prunus* of subfamily *Amygdaloideae* (syn. *Prunoideae*), family *Roseaceae* [5]. Different plum varieties (Beauty, Faramusa, Fazlemananai, and Late Mananai) are cultivated in varying quantities in a variety of climate zones that are neither too hot nor too cold. Mardan, Kalat, Nowshera, Mastung, Peshawar, Quetta, Pishin, and Swat are the major plum-producing regions in Pakistan. With a cumulative output of 67,000 tons, Pakistan is ranked 17th in the world in plum production. The province of Khyber Pakhtunkhwa contributes about 47% of the country's overall plum output, while the Swat district alone contributes about 17% [6].

The plum fruit is mostly consumed domestically, with a small amount shipped to neighbouring countries, such as India, Sri Lanka, Bangladesh, and Gulf countries. The fruit is used for making several products. It is a rich source of compounds that have a positive impact on human well-being and help to avoid the onset of many diseases [7]. Plum is high in bioactive substances (such as phenolic acids), organic acids (such as citric and malic acids), and minerals (such as potassium, phosphorus, calcium, and magnesium). It is used in many dishes, such as for making desserts. It is high in iron, vitamin A (beta-carotene), vitamin C (ascorbic acid), and fibers. It is eaten in fresh, dried, and frozen forms, and also used in jellies, jams, and other beverages. It is preferable to dehydrate plums to preserve their nutritional and sensory properties since they have a high sugar level and can be dried without fermenting. The fruit is dried

using a variety of traditional and innovative drying methods, including hot air drying, sun drying, vacuum drying, microwave drying, high-pressure aided drying, and osmotic dehydration. Plums are usually dried to achieve low microbial loads and to provide a more durable commodity that can last the course of seasons during the year [8, 9].

Plum fruit enjoys a high demanded overseas due to its nutritional value and health benefits. So, the cultivation of high-quality plum fruit is important. However, plum trees take time to mature and bear fruit in cold regions due to slow root growth. Although, with appropriate cultivation methods, it can also be grown in other areas of Punjab. Plum trees are very productive because of their profuse flowering, high-yield production, and early ripening habits of cultivars recommended for plains [10]. There is no reliable and thorough research available which addresses the nutritional quality and yield performance of plum varieties namely Herisminar, Methley, Red Beaut, Santa Rosa, and Shakar Prune cultivated in Punjab, Pakistan. Hence, this study intends to evaluate the nutritional potential of all these plum types to fill this gap.

2. MATERIALS AND METHODS

The current study was designed to evaluate the nutritional quality of the plum varieties grown in Punjab, Pakistan. For this purpose, fifteen samples (approximately one kilogram) of each plum (*Prunus domestica*) variety were collected from the Horticultural Research Station, Nowshera (Soon Valley), Pakistan in May 2021. The geographical coordinates of the studied area are (32°33'52.7"N, 72°08'27.8"E) (Figure 1). These varieties included Methley, Shakar Prune, Santa Rosa, Hersminar, and Red Beaut. The analysis was performed at the Biochemistry Section, PHRC, Ayub Agriculture Research Institute, Faisalabad (Figure 1). Data regarding the physico-chemical parameters including fresh weight, pulp percentage, acidity (malic acid), total soluble solids (TSS), total sugar, and reducing and non-reducing sugar were collected.

2.1. Agricultural Practices

Plum plants were planted on a well-drained, fertile, and loamy soil with a planting distance of 5 m × 4 m. Based on soil analysis, the plum orchard was fertilized using the following the recommendations (30 g N, 26 g P_2O_5, 18 g K_2O with 5 kg farmyard manure per plant). Potash and phosphorus fertilizers were applied in the form of superphosphate and muriate of potash with farmyard manure in December. The amount of nitrogenous fertilizer (urea) was split into two halves. The first half was applied in February and the second half in April. Additionally, foliar spray of iron and zinc sulphate with unslaked lime was applied in March in a 1:1:1 ratio when the plum fruit became pea-sized.

2.2. Experimental Analysis

Plums were harvested when they were physiologically mature. Approximately, 01 kg of plum per replicate was selected from each variety randomly and analyzed for the different physico-chemical characteristics. Physical parameters included fruit weight (g/fruit), fruit pulp (%), and fruit color (flesh, ground, and skin color). Royal Horticultural Society (RHS) Color Chart 2001 was used to record data on fruit color [11]. The fruit weight was determined using a Puchun brand digital electronic balance with the model number JA2003B and its value was recorded in grams [12, 13].

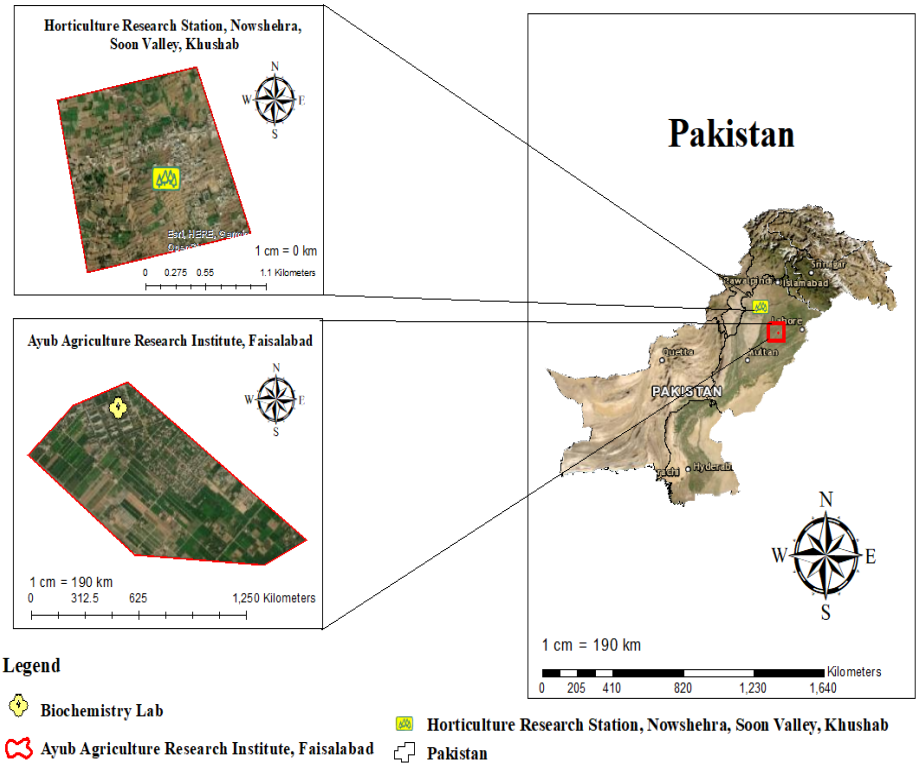

Figure 1. Location of the Research Station and Sample Analysis Laboratory

After calculating the fruit weight (g/fruit), the peeled plum fruit was sliced into two halves and the seed was removed. To make a soft blend, the pulp was put in the National juicer. The blended pulp was weighed on the same scale used to weigh the whole fruit and the gram weight of the pulp was recorded. The following formula was used to calculate the pulp percentage:

$$\text{Pulp \%} = \frac{\text{Pulp Obtained (g)}}{\text{Fresh Fruit wt (g)}} \times 100$$

Biochemical characteristics included the calculation of total soluble solids (TSS) calculated using an ATAGO company handheld pocket refractometer (PAL-1), equipped with external light interference to determine the refractive index. It is suitable for a wide range of products including fruit juices, drinks, and industrial fluids, with a Brix measurement range of 0.0–53.0%. Titration method was used to determine titratable acidity. A National company juicer was employed and 10 ml of plum juice was extracted and transferred to a 250 ml beaker containing 50 ml of distilled water. The solution was then tinted pink by adding three drops of phenolphthalein. The colored solution was titrated against 0.1 N NaOH, until a colorless end point was recorded. The results were expressed as a percentage of malic acid using the following formula:

$$\text{Percentage malic acid} = \frac{\text{Titrate} \times \text{Acid Factor}}{10\text{ml Juice}} \times 100$$

$$\text{Percentage malic acid} = \text{Titre x Acid factor x } 10$$

Factor for malic acid = 0.0067 (malic fruit)

Total sugars, reducing sugars, and non-reducing sugars of plum juice were estimated using Fehling's solution method, as described by [14]. The percentage of reducing sugars was determined by using standard sugar solution (X) and by taking 10 ml aliquot sample (Y) in a 250 ml volumetric flask containing 100 ml distilled water, 25 ml lead acetate solution, and 10 ml potassium oxalate solution. Then, Fehling's solution was added while slow boiling continued and brick red ppt. was appeared. The percentage of reducing sugars was calculated using the following formula:

$$\text{100 g or 100 ml sample/juice contains} = \frac{6.25 \times (X)}{(Y)} \text{ g OR \% of reducing sugars}$$

For total invert sugar, a 25 ml aliquot was prepared and placed in a 100 ml flask. Afterwards, the solution was treated with 20 ml of water and 5 ml of hydrochloric acid and allowed to stand overnight to complete hydrolysis. Then, the solution was neutralized with 5 N NaOH by using phenolphthalein indicators. The reading of the aliquot used from the burette against 10 ml of Fehling's solution (Z) was noted. The percentage of total invert sugar was calculated using the following formula:

$$\text{100 g or 100 ml sample/juice contains} = \frac{25 \times (X)}{(Z)} \text{ g or \% total invert sugar}$$

The percentage of non-reducing sugars was determined by using the subtraction method. Using this method, the percentage of reducing sugars was subtracted from the percentage of total invert sugars to get the percentage of non-reducing sugars.

Non-reducing sugars (%) = Total invert sugars (%) - Reducing sugars (%)

2.3. Statistical Analysis

Statistical analysis of the data was carried out using the statistical software Statistix 8.1. For significant differences between treatments, the means were compared using the least significant difference (LSD) test [15].

2.4. Climatic Conditions of Soon Valley

The geographical coordinates of the studied area are (32°33'52.7"N, 72°08'27.8"E) [16]. Soon Valley is classified as semiarid with 5.1 mm evapotranspiration and receives sunshine 8.4 hours/day [17]. The average precipitation (mm) and temperature (°C) of Soon Valley is presented in Figure 2. The graph shows that the average annual temperature and total precipitation of the studied area are 28.7°C and 568.8 mm, respectively. Data regarding the climatic condition of the studied area was taken from [18].

3. RESULTS

3.1. Fruit Color

The flesh, ground, and skin color of the studied plum varieties are illustrated in Figure 3. The flesh color of Methley, Shakar Prune, Santha Rose, Hersminar, and Red Beaut was dark red, red-yellow, and yellow for the last four verities, respectively. Ground color of plum varieties was blue, red, grey-purple, grey, and red, respectively. The skin color of varieties (Methley, Shakar prune, Santha rose, Hersminar, and Red Beaut) was greenish-yellow, dark red, grey-purple, and red (Table 1).

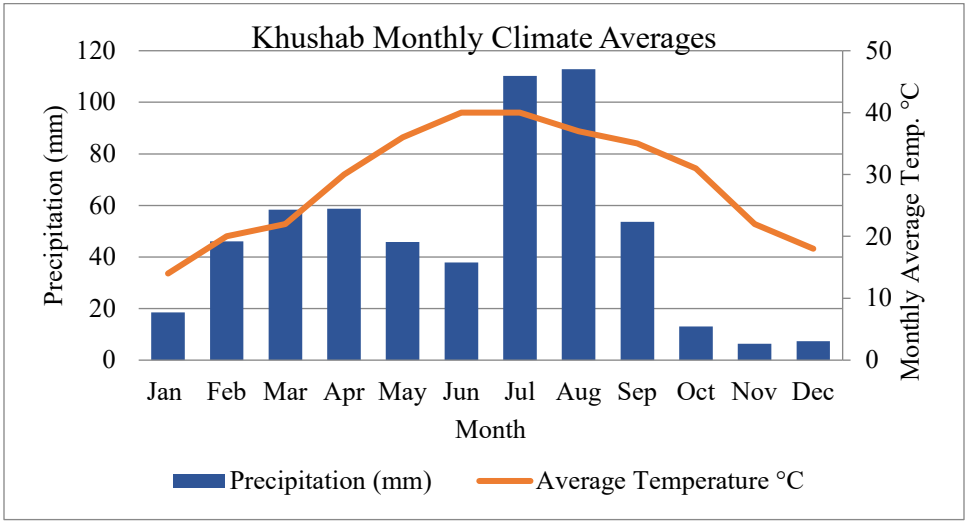

Figure 2. Monthly Average Precipitation (mm) and Temperature °C

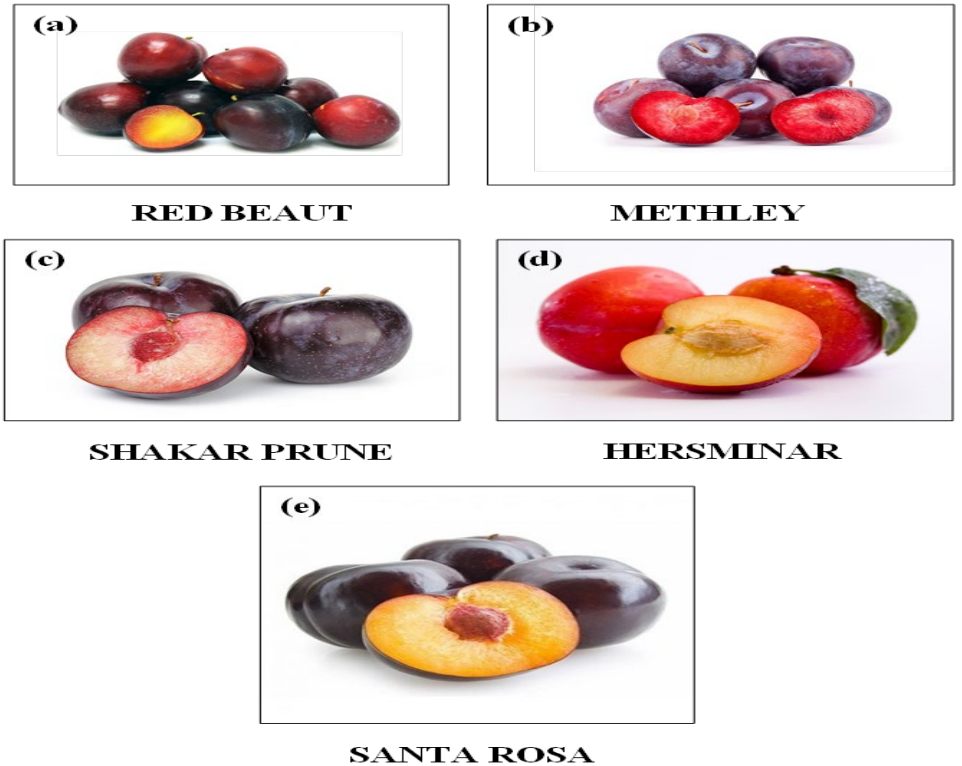

Figure 3. Comparison of the Flesh and Ground Colors of The Various Varieties of Plums

Table 1. Flesh, Ground, and Skin Colors of Plums of Different Varieties

Varieties	Fruit Color		
	Flesh Color	Ground Color	Skin Color
Methley	Dark Red	Blue and Red	Greenish Yellow
Shakar Prune	Yellow and Red	Red	Dark red and yellow
Santa Rosa	Yellow	Grey purple	Dark purple
Hersminar	Yellow	Grey	Red
Red Beaut	Yellow	Red	Red

3.2. Fresh Weight

Fresh fruit weight is a varietal property, which may fluctuate depending on the climatic and agricultural conditions, as well as the number and position of fruits on a tree. The fresh weight of fruit is expressed in grams per fruit (Table 2). Walkowiak-Tomczak in 2008 categorized the plum fruit into six classes on the basis of fruit size as very small (5-10 g), small (10-20 g), medium-sized (20-40 g), rather large (40-50 g), large (50-60 g), and very large (60-80 g) fruit [19]**.** Among analyzed cultivars, the smallest fruit was found in Methley (12.4 g), followed by Shakar Prune (17.5 g) which was classified as small fruit. While, cultivar Santa Rosa and Hersminar had medium-sized fruits in terms of weight, weighing (30.9 g) and (26.3 g), respectively. The fruit of Red Beaut was reported as a large fruit with a weight of 52.9 g per fruit, as shown in (Table 2).

3.3. Pulp (%)

Tested plum varieties Santa Rosa and Red Beaut differed considerably in terms of pulp (%). Although, the plum varieties Methley, Shakar Prune, and Hersminar showed a non-significant variation for pulp (%) (Table 2). Plums of the variety Red Beaut contained a maximum pulp content of 86.7%, followed by Santa Rosa with a pulp content of 82.2%. All other varieties had pulp content much less than Red Beaut and Santa Rosa (Table 2).

3.4. Titratable Acidity (%)

The maximum acidity (1.35%) was recorded in Methley. Whereas, the minimum acidity (0.99%) was found in the cultivar Red Beaut. Hersminar (1.24%) was statistically at par with Shakar Prune (1.23%) in terms of titratable acidity (Table 2).

Table 2. Fresh Weight, Pulp (%), and Acidity (%) of the Studied Plum Varieties.

Varieties	Fresh weight (g/fruit)	Pulp (%)	Acidity (%)
Methley	12.4 e	78.5 c	1.35 a
Shakar Prune	17.5 d	80.0 c	1.23 b
Santa Rosa	30.9 b	82.2 b	1.08 c
Hersminar	26.3 c	78.9 c	1.24 b
Red Beaut	52.9 a	86.7 a	0.99 d
LSD (5%)	3.07	1.93	0.07

Table 3. Total Soluble Solids (%), Reducing Sugars (%), Total Sugars (%), Non-Reducing Sugars (%) of the Studied Plum Varieties

Varieties	TSS (%)	Reducing Sugars (%)	Total Sugars (%)	Non-reducing Sugars (%)
Methley	16.5 ab	6.74 a	10.4 c	3.45 c
Shakar Prune	16.4 b	6.70 ab	12.2 a	5.26 a
Santa Rosa	10.2 d	6.72 ab	10.9 b	4.00 b
Herisminar	14.8 c	6.51 bc	10.0 c	3.34 c
Red Beaut	17.3 a	6.39 c	10.1 c	3.54 bc
LSD (5%)	0.76	0.21	0.46	0.53

3.5. Total Soluble Solids (%)

Table 3 depicts TSS values ranging from 10.2% to 17.3%, while the overall average TSS is 15.04%. The highest TSS value (17.3%) was recorded in the cultivar Red Beaut and the lowest (10.2%) was recorded in the cultivar Santa Rosa. Methley showed a non-significant variation for TSS with the cultivar Shakar Prune and Red Beaut (Table 3).

3.6. Total, Reducing, and Non-Reducing Sugars (%)

The maximum total sugars content (12.2%) was observed in Shakar Prune, followed by Santa Rosa (10.9%). All the other varieties showed a non-significant variation with Herisminar which showed the minimum total sugars content (10.0%), as presented in Table 3. The maximum reducing sugars content (6.74%) was recorded in the cultivar Methley which was at par with the cultivars Santa Rosa (6.72%) and Shakar Prune (6.70%). The minimum reducing sugars content (6.39%) was found in the cultivar Red Beaut which was comparable with Herisminar (6.51%). The maximum non-reducing sugars content (5.26%) was recorded in the cultivar Shakar Prune which was significantly higher than the rest of the cultivars. The minimum non-reducing sugars content (3.34%) was recorded in the cultivar Herisminar which was statistically at par with Red Beaut (3.54%).

4. DISCUSSION

Skin color depends on variety, soil nutrients status, sunlight, temperature, plant location, tree growth, and biomass. It determines the physical appearance of plums which is influenced by harsh environmental conditions [19]. Methley contains a dark-red flesh color called bloom plum. The findings in terms of fruit color coincide with the findings of Salazar et al. [20] and Sundouri et al. [21]. They concluded that flesh color is due to the genetic characteristics of plums, depends on the maturity level, and is strongly affected by climatic conditions at the time of maturity.

Kumar et al. [22] reported high heterogeneity in average fruit weight of plum varietals. According to [23], the weight of Santa Rosa may be 29.44 ± 2.5 g/fruit. However, it needs to be mentioned here that fruit size and pulp content are highly variable parameters, dependent on weather conditions in a given vegetation season [24].

Fruit titratable acidity, in general, determines customer satisfaction [25]. Plum source has a significant impact on

cultivar titratable acidity [26]. Total titratable acidity (TTA) and organic acids (malic acid, citric acid, and lactic acid) found in fruit juice are primarily responsible for the sour taste [10]. The current findings on titratable acidity are similar to the findings of Kumar et al. [23] and Bist and Sharma [27], who recorded values ranging from 1.09% to 2.92%.

For plums, TSS is the most important property which demonstrates the fruit quality [28, 29]. These values are consistent with the findings of Son et al. [11] , who reported that different soil and climatic conditions and management practices are the reasons behind the differences in TSS contents in different plum varieties. Thakur et al. [30] revealed that TSS ranged from 11.53% to 16.06% in the selected set of cultivars, while Moghaddam et al. [31] reported a greater variability in TSS ranging from 12.1% to 23.55%. Crisosto et al. [25] stated that for the direct consumption of plum the minimum acceptable TSS value is 12%. All the tested varieties except Santa Rosa achieved this value. This variation in TSS may be due to the climatic conditions of Punjab, Pakistan.

The findings regarding reducing and non-reducing sugars for Santa Rosa are consistent with the findings of Suklabaidya et al. [27], who reported that reducing sugars, total sugars, and non-reducing sugars in fruits tend to increase significantly with the increasing pruning severity. Sugar contents in plum fruit depend on the variety, time of harvest (maturity), and climatic conditions. The above authors also reported a substantial rise in sugar contents under water deficit conditions [27].

4.1. Conclusion

The study concluded that there was no significant variation among the quality parameters of Methly and Herisminar in terms of pulp percentage and reducing sugars. Whereas, all five varieties showed significant variation in terms of fresh weight, total soluble solids (TSS), and total sugars. The findings established that plum varieties have a significant impact on their productivity and overall health. Premised on the outcomes of this study, the Red Beaut and Shakarprune cultivars are recommended for cultivation in the plains of Punjab, Pakistan.

4.2. Implications

The evaluation of nutritional qualities and yield performance of different plum (*Prunus domestica*) varieties grown in Punjab, Pakistan holds immense potential for the future of agricultural research and economic growth in the region. With the increasing demand for nutritious and high-quality plum fruits, this study can pave the way for the cultivation of more productive and profitable plum varieties in the region. Moreover, the identification of the best-performing plum varieties based on their nutritional value and yield can help farmers in making informed decisions and maximizing their economic output. In this way, this study can contribute to the overall development and sustainability of the agriculture sector in Punjab, Pakistan.

Conflict of Interest

The authors have reported no conflicts of interest.

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