EFFECT OF FRUIT RIPENING STAGES ON STRAWBERRY (*FRAGARIA X ANANASSA.* DUCH*)* FRUIT QUALITY FOR FRESH CONSUMPTION

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ABSTRACT

The study was conducted during 2010-11 at Department of Horticultural Sciences, University of Agriculture, Peshawar, Pakistan to investigate the influence of fruit ripening stages of Strawbery on its fruit quality. The fruits were harvested at three stages i.e. pink, red and dark red for analysis of physico-chemical quality attributes. The fruit harvested at pink stage showed higher moisture content (92%), titratable acidity (1.30%) and ascorbic acid (50.43 mg/100 g) but lower organoleptic quality score (4.00), due to more acidity (1.30%) and low total soluble solids (TSS) (5.27 °Brix). Whereas, the fruits harvested at red stage had superior organoleptic quality with 7.00 score due to optimum moisture content (90.90%), TSS (5.87 °Brix), titratable acidity (1.27%), TSS/acid ratio (4.62) and ascorbic acid (40.28 mg/100 g). Delaying harvesting up to dark red stage increased the TSS (6.14 °Brix), TSS/acid ratio (5.29), pH (3.40) and sensory score (8.00) but the least moisture content (89.22%), titratable acidity (1.16%) and ascorbic acid (31.87 mg/100 g) were shown. It can be concluded that strawberry fruits if harvested at red stage had optimum moisture content, TSS, TSS/acid ratio, TA, pH, ascorbic acid and organoleptic quality score. Hence it should be harvested at red stage for fresh consumption.

KEYWORDS: ***Fragaria x ananassa*; fruit quality; development stages; organoleptic properties; physico-chemical properties; Pakistan.**

INTRODUCTION

Strawberry (*Fragaria x ananassa. Duch*) is a non-climacteric fruit and do not ripen off the plant (19). Hence, it is generally harvested at or near fully ripened stage to obtain the best edible fruit quality (25). Decision of harvesting is critical because the quality of strawberry fruit may vary at different stages of maturity (15). According to Pinel *et al.* (31), the strawberry fruit contain the higher TSS content at red ripened stage but higher total phenolics, total ellagic acid and vitamin C at the pink stage of maturity. Ascorbic acid is a water soluble nutrient and essential for maintaining normal growth and development in human beings (33). Strawberry is a good source

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of ascorbic acid, anthocyanins and flavonoids (6, 43). Strawberries at pink stage had the highest content of Ascorbic acid, which declined with advancement in maturity (31, 39). The decline in ascorbic acid with advancement in maturity reveled that ascorbic acid is quite unstable vitamin and decreased with advance in maturity stages (32, 33).

The anthocynins, a well know antioxidant of strawberry fruit concentration increases between the white and pink stages but then decreased at fully developed stage (15, 42). Several studies have shown that strawberry fruit harvested at early stages of color development, can change color during storage, but may not change in sugar and acid content to be suitable for fresh consumption (9, 19, 37). Hence the fruit is generally harvested at full ripened stage that reduced quality rapidly due to nutrients and water loss which also increased the susceptibility (4, 10, 27). Moreover, the strawberry fruit harvested at dark red stage is tender and vulnerable to pathogens, with more post harvest losses and lesser shelf life (2). The optimum harvest time of fruit strawberry is estimated on the basis of surface color development, but appearance, firmness, flavor and nutritional value are also important quality characteristics to have greater consumer acceptance and market demand (15, 44). The strawberry fruit can be harvested at different stages during color development i.e. color break, half colored, three quarters colored and full red colored, based on the first appearance and subsequent development of red color (24). The maturity index used for harvesting is the red color resulting from anthocynin synthesis corresponding to half or three fourths of the fruit (22). When strawberry was harvested at three-quarter color development stage, its keeping quality, appearance, color, and firmness as well as acidity and TSS with minimum fruit decay was superior to fruit harvested at fully ripened stage (30).

The organoleptic quality evaluation of strawberry fruit is a common sensory method of evaluating fruit quality (13, 14). While, the fruit size, appearance, color, texture, flavor and aroma are important sensory attributes of the strawberry fruit quality, chemical characteristics such as TSS, acidity and ascorbic acid content are also important because they influence the sensory quality (12, 31, 35, 36). The overall quality is thus, determined by a specific combination of chemical compounds especially, the sugars, organic acids, and volatiles compounds as well as good color and flavor (8, 35). The acidity of the fruit is due to the presence of different organic acids (41). The highest contribution to total acids in strawberry fruit is by citric acid and malic acid (17, 39). Most of the fruits have relatively high acidity at early stages of development and hence are less desired as compared to more mature

stages (18).Thus, it is likely to observe better quality score of fruits harvested at fully ripened stage as compared to earlier stages of maturity (21).

In Khyber Pakhtunkhwa, Pakistan most of the strawberry growers are less vigilant about the optimum stage of maturity for harvesting especially with reference to fresh consumption, processing, local or distant marketing (34). Harvesting at proper maturity is important not only for getting high price in the market but also for its utilization with maximum physico-chemical quality attributes (15). The present research was therefore initiated to see the influence of fruit ripening stage on the quality of strawberry fruits for local markets and fresh consumption.

MATERIALS AND METHODS

The present study was conducted at the Department of Horticulture, University of Agriculture, Peshawar, Pakistan to investigate the influence of different fruit ripening stages on strawberry fruit quality during the year 2010-11. For this purpose strawberry fruits were harvested at pink, red and dark red stages and following quality parameters were investigated.

Moisture content (%): A known weight of fruit sample was taken in a petri dishe and kept at 105 °C in an oven till constant weight obtained. The loss in weight after drying was noted and percent moisture content was calculated (1).

Organoleptic evaluation: Strawberry fruits were evaluated at harvest (Fresh fruits) by a panel of judges for fruit quality attributes such as color, taste, aroma, texture and overall acceptability. Organoleptic score of 1-9 was assigned to samples according to quality of fruits, where 9 represented like extremely; 8 like very much; 7 like moderately; 6 like slightly; 5 neither like nor dislike; 4 dislike slightly; 3 dislike moderately; 2 dislike very much and 1 dislike extremely (20).

Ascorbic acid (mg/100 g): The vitamin C (ascorbic acid) in strawberry fruit was calculated by Titrimatric method (33).

Titratable acidity (%): Acidity percentage (TA) of strawberry fruits was determined at harvest by acid neutralization method (1).

PH: The pH of strawberry fruits harvested at different stages of maturity was determined with the help of electronic pH meter, [Model HI-111, Hann instrument, MBH engineering, Lynnfield, USA]. A well mixed 50 ml strawberry

juice was taken in 100 ml beaker and the electrode of pH meter was dipped in the paste and reading was noted. The same procedure was repeated for all treatments. The electrode of pH meter was properly washed with distilled water and dried with tissue paper after recording pH of every sample.

Total soluble solids (%): Total soluble solids (TSS) of strawberry fruits harvested at different maturity stages was recorded at harvest by using a hand refractometer (Kernco, Instrument Co, Texas) (1).

TSS/acid ratio: The total soluble solids/acid ratio was calculated by using the following formula.

$$TSS/acid\ ratio = \frac{TSS}{TA}$$

The experiment was laid out in RCBD with three treatments i.e. maturity stages of the fruit and the treatments were replicated thriice. The data calculated on different parameters of strawberry fruits harvested at different stages of maturity were subjected to analysis of variance (ANOVA) technique to observe the differences between the different treatments. In cases where the differences were significant, the means were further assessed for differences through LSD test at 5 percent level of probability as described by Steel and Torrie (38). Statistical computer software, Statistix-9 (USA) was applied for computing both the ANOVA and LSD.

RESULTS AND DISCUSSION

Moisture content (%)

The data (Table 1) revealed that moisture content of strawberry fruits were differed significantly in fruits harvested at different stages of maturity. The highest moisture content (92.39%) was recorded in pink fruit followed by red fruit (90.90%), while lowest moisture content (89.22%) was observed in dark red fruit. Moisture content of strawberry fruit at different stages of fruit development is important for consumer point of view. Most of the consumers prefer firm strawberries which do not lose too much juice when sliced (15). Generally strawberry fruits harvested at optimum stage of maturity contained approximately 89 percent moisture (40). Higher moisture content was recorded at pink stage which gradually decreased at red and further at dark red stage of maturity (12). Variation in moisture content of strawberry fruit from pink stage of maturity to dark red stage is due to compositional changes

occurring during strawberry fruit development and ripening (37), which includes conversion of starch into sugars when strawberry fruits proceed towards maturity and further at ripening, hence affect moisture content of strawberry fruits (9).

Table 1. Physico-chemical analysis of strawberries harvested at different stages of fruit ripening.

Harvesting stage	Moisture content (%)	Organoleptic quality score	Ascorbic acid (mg/100g)	Titratable acidity (%)
Pink	92.39a	4.00b	50.43a	1.30a
Red	90.90b	7.00a	40.28b	1.27a
Dark red	89.22c	8.00a	31.87c	1.16b
Significance Level	**	**	**	*
$LSD_{(0.05)}$	1.02	1.77	1.42	0.08

Harvesting stage	pH	TSS (°Brix)	TSS/ Acid Ratio
Pink	3.10 b	5.27 b	4.05 c
Red	3.27 ab	5.87 ab	4.62 b
Dark red	3.40 a	6.14 a	5.29 a
Significance Level	*	*	**
$LSD_{(0.05)}$	0.20	0.68	0.13

Means followed by similar letter(s) in column do not differ significantly from one another
* = Significant, ** = Highly significant

Organoleptic quality score

The data collected on organoleptic quality revealed that strawberry fruit varied significantly with maturity stages at harvest. Least score (4.00) was marked for fruits harvested at pink stage. The fruits harvested at red and dark red stages got 7.00 and 8.00 points respectively with the difference being non-significant. The fruits harvested at red stage were responded greatly by the panel of judges (Table 1). Strawberry is a non-climacteric fruit and do not further ripen after harvest, therefore, it should be harvested at or near fully ripened stage to obtain the best edible quality (19, 25). The lowest organoleptic quality score recorded at pink stage may be for the reason that pink stage strawberry is generally unripe, high in organic acids and low in sugars and as a result attained lowest organoleptic quality score. But at red and dark red stages of maturity, highest TSS and TSS/acid ratio was recorded as compared to pink stage of maturity (Table 1). But recorded higher organoleptic quality score, as taste of strawberry fruit is determined by a proper balance between acidity and sugars in fruit (21). Flavor of strawberry fruit is characterized by several factors such as sweetness, acidity, astringency in combination with aroma, due to the presence of

different volatile compounds (15, 21). Hence at optimum maturity (red stage) balanced amount of sugars, acids and volatile compounds recorded highest organoleptic quality score in the present study.

Ascorbic acid (mg/100 g)

Ascorbic acid content of strawberry fruits harvested at different stages of maturity was significantly different. The highest ascorbic acid content (50.43 mg/100 g) was recorded at pink stage followed by red stage (40.28 mg/100 g) while the least (31.87 mg/100 g) was recorded at dark red stage (Table 1). Strawberry is a good source of ascorbic acid, anthocyanins and flavonols (6, 33), it is an essential nutrient for maintaining normal growth and development in human beings. Strawberries at pink stage of maturity recorded the highest content of ascorbic acid, which declined with advancement in maturity from red to dark red stage of development (31, 39). The decline in ascorbic acid from pink to red and further reduction with advancement in maturity to dark red stage revealed that ascorbic acid (vitamin C) is quite unstable vitamin and generally decreases from pink stage of development to red and further to dark red stage in strawberry fruit (32, 33). Ascorbate oxidase has been proposed to be the major enzyme responsible for enzymatic degradation and reduction of ascorbic acid when the fruit proceeds toward maturity from pink to dark red stage of maturity in strawberry fruits (19).

Titratable acidity (%)

The titratable acidity (TA) of strawberry was significantly affected by harvesting the fruits at different stages of maturity. The highest TA (1.30%), was recorded at pink stage declined to 1.27 percent at red stage, with the difference being non-significant. The minimum TA (1.16%) was recorded at dark red stage of maturity (Table 1). The acidity in fruit is an important factor in determining fruit maturity and quality (28). The consumers' acceptance is also determined by a proper balance between acidity and TSS or sugars (21). Hence, specific sugar-acid ratio is used as maturity and quality standards in marketing especially international trade (41). The acidity of strawberry fruit, generally, increases to maximum in mature fruit before declining more rapidly in the later stages of ripening (37). The decline in acidity is attributed to increasing consumption of organic acids in the process of respiration resulting decreased acidity as the fruit advances from one stage of development to another (16, 26). As the fruit advances in maturity, organic acids concentration decreases while those of soluble sugars increases resulting in increased pH (46) but become relatively stable at

ripened stage of maturity (3, 25). Strawberry flavor depends on a balance between sugars and acids expressed in ripe fruits, organic acids are the second contributors after sugars to the total soluble solids of strawberries (6).

pH

The data regarding pH of strawberry fruit revealed significant differences with different stages of maturity. The highest pH (3.40) was recorded in fruits harvested at dark red stage followed by fruits harvested at red stage (3.27) while the least pH (3.10) was recorded at pink stage (Table 1). The pH of strawberry cultivars at different stages of maturity ranged between 3.6 and 4.1 (11). With the advancement of fruit in maturity organic acids concentration decreases. The organic acids are consumed in the process of respiration and the acidity of fruit, therefore, decline as the fruit advances from one stage of development to another while soluble sugars increases resulting in increased pH but become relatively stable at ripened stage of maturity (16, 26, 28, 46).

Total soluble solids

Significant variations were observed in total soluble solids (TSS) of strawberry fruits harvested at different stages of maturity. The highest TSS (6.14 °Brix) was recorded in fruits harvested at dark red stage, followed by red stage (5.87 °Brix) and the least TSS (5.27 Brix%) was recorded at pink stage (Table 1). Sugars and organic acid are the main contributors to TSS of strawberry fruit and a higher value of TSS is related to highest sugars in fruits (5, 6). It has been reported that TSS plays important role in determination of optimum maturity and it increases at maturity and ripeness from pink to dark red stage of strawberry due to the conversion of starch into sugars (23). Another reason for TSS increase from pink stage of maturity to red and further to dark red stage may be due to the concentration of sugars and organic acids at advanced stage of maturity. As moisture content of strawberry fruit decreases when the fruit proceeds towards maturity and further to ripening as a result TSS get concentrated and increase (12).

TSS/acid ratio

The TSS/acid ratio of strawberry fruit was significantly affected by harvesting the fruits at different stages of maturity. The highest TSS/acid ratio (5.29) was recorded in fruits harvested at dark red stage followed by red fruit stage (4.62). The lowest TSS/acid ratio (4.05) was measured in fruits harvested at

pink stage of maturity (Table 1). A specific TSS/acid ratio is essential for characteristic flavor of a fruit and, hence, is used as a sign of edible maturity (21). At the beginning of the ripening process the TSS/acid Ratio is low, because of low sugars and high acid content, resulting in sour taste of fruits (45). During the ripening process the fruit acids are used in respiratory metabolism, while the sugar content increases, thus the TSS/acid ratio, generally increases with advance in maturity (7, 16, 29). The loss of characteristic flavor in over ripened fruits can be attributed to very low levels of fruit acid that alters the TSS/acid ratio (31).

CONCLUSION

Strawberries harvested at red stage had optimum moisture content, total soluble solids, TSS/acid ratio, titratable acidity, pH, ascorbic acid and organoleptic quality score while highest total soluble solids, TSS/acid ratio and sensory score were recorded at dark red stage but the same stage had the least moisture content, titratable acidity and ascorbic acid. It can be concluded that strawberry fruit harvested at red stage were superior for most of the quality attributes, hence should be harvested at this stage for fresh consumption.

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