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Correlation and Linear Regression of Physico-biochemical Attributes of Ber (*Ziziphus mauritiana*) cv. Umran During Ambient Storage

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Authors' contributions

This work was carried out in collaboration among all authors. Author JSS designed the study and wrote the protocol. Authors LNB and MRC managed the literature searches, performed the statistical analysis. Authors MS and MLJ managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The objective of the study was to investigate the correlation and linear regression between the physical and biochemical characteristics of Indian jujube (*Ziziphus mauritiana* Lamk.) cv. Umran, which have been influenced by post-harvest treatments during storage under ordinary room conditions.

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Place and Duration: The experiment was carried out at the Department of Horticulture, Sri Karan Narendra Agriculture University, Jobner, Rajasthan from February 2019-20.

Methodology: Calcium chloride ($CaCl_2$) (0.5, 1.0 and 2.0%) and gibberellic acid (GA_3) (20, 40 and 60 ppm) were used to treat the fruits after harvesting. The treated fruits were then stored under normal or ambient room conditions. In present study evaluated physical attributes, such as physiological weight loss, decay loss, marketability, pulp content and biochemical parameters i.e., total soluble solids, titratable acidity, ascorbic acid content and total sugars content. The Pearson correlation coefficient (r) and simple linear regression were used to calculate the relationship between fruit weight and various physico-chemical attributes.

Results: The correlation analysis showed a significant positive correlation between the weight of fruit and quality attributes, including marketability ($r = 0.953$), pulp content ($r = 0.847$), total soluble solids ($r = 0.931$), titratable acidity ($r = 0.961$), ascorbic acid ($r = 0.984$), and total sugars ($r = 0.961$) at 9th day after storage. Whereas, a significant negative correlation was found between the weight of the fruit and physiological loss in weight ($r = -0.943$) and decay loss ($r = -0.953$). Linear regression models provided more support for these correlations, showing that variations in fruit weight accounted for a significant proportion of the variability in the assessed quality parameters. The coefficients of determination (r^2) ranged from 0.718 to 0.968.

Conclusion: The robust correlations and regression models inform evidence-based storage techniques and reducing fruit quality losses during ambient storage.

Keywords: Ber; ambient storage; umran; correlation; linear regression.

1. INTRODUCTION

The ber, known scientifically as *Ziziphus mauritiana* Lamk. and commonly referred to as the Indian Jujube is a fruit of significant economic and nutritional importance widely cultivated in India and China. It belongs to the Rhamnaceae family and has a rich history of cultivation and is often described as a "Poor man's fruit " due to its low cost and accessibility [1]. The ber thrives in the arid and semi-arid regions of Northern India, where it is well-adapted to arid and semi-arid climates. Major ber growing states in India include Gujarat, Rajasthan, Madhya Pradesh, Haryana, Punjab, Bihar, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, West Bengal and Assam [2]. As of recent data, India has approximately 47.92 thousand hectares for ber cultivation with an annual production of 512.03 thousand metric tons [3]. Rajasthan is a major producer with an area of 1.11 thousand hectares under cultivation and annually production of 9.59 thousand metric tons with the average productivity about 8.64 tons hectare^{-1} [3].

Nutritionally, ber fruit is highly rich in vitamins and minerals content. The fruit's pulp contains 13-19% total soluble solids (TSS) and 0.20 to 0.60% acidity at fully mature stage. It is significantly high in vitamin C after guava and aonla among fruits, making it a critical component of dietary vitamin C intake. Furthermore, ber contain a good amount of protein (0.8g 100g^{-1}), phosphorus (0.148%) and iron (0.54%) [4]. The fruit also contains a diverse range of amino acids, including asparagine, aspartic acid, arginine, glutamic acid, serine, glycine, threonine, α-alanine, valine, methionine, leucine and isoleucine, which contribute to its nutritional profile [5]. Despite its nutritional benefits, ber is highly perishable and at present time have significant storage challenges [6]. The fruit's lower shelf life under ambient conditions necessitates effective post-harvest management to preserve its quality. Various strategies have been used to address this issue, including the use of gibberellic acid (GA_3) to delay ripening and reduce senescence. GA_3 influences the metabolism of carbohydrates and the production of sucrose, while calcium aids in regulating the ripening process and maintaining fruit texture [7,8]. The enzymatic activity of PG and PME in fresh-cut dragon fruit were reduced after treatment with $CaCl_2$ [9]. Calcium has a crucial role in preserving the structural integrity of cell walls. An excessive amount of calcium from external or internal sources hinders the ripening process by decreasing enzyme activity [10].

Correlation and regression analysis are crucial for understanding the physico-biochemical attributes of fruits and their impact on quality. These statistical tools help in elucidating how different fruit characteristics interrelate and influence overall fruit quality. For instance, correlation studies have revealed significant relationships between various attributes. Rahman et al. [11] demonstrated a notable correlation between fruit size and total soluble solids (TSS) in mangoes, indicating that larger fruits tend to have higher sugar content. Similarly, Ali et al. [12] found a positive correlation between fruit weight and TSS, reinforcing the idea that larger fruits often exhibit increased sugar levels. Regression analysis is employed to predict fruit quality attributes based on various factors. In a study on guava fruit, Singh et al. [13] utilized multiple linear regression to model the relationship between fruit color, firmness, and TSS. Their regression model effectively predicted fruit sweetness based on these attributes, offering valuable insights for optimizing fruit harvest and storage practices. While correlation analysis is essential for identifying the relationships between different physico-biochemical attributes, it does not establish causation. To determine the causal effects of individual attributes on overall fruit quality, linear regression analysis is necessary. For example, Asmamaw et al. [14], Singh et al. [15] and Hernández et al. [16] highlight that linear regression quantifies the impact of each physico-biochemical characteristic on fruit quality, taking into account multiple predictor variables such as physiological loss in weight, TSS, sugar content, and acidity.

This research aims to fill existing gaps in knowledge by conducting a thorough investigation of the correlation and linear regression of the physico-biochemical characteristics of *Ziziphus mauritiana* cv. Umran. The study will provide valuable insights for stakeholders in the agricultural sector, including farmers, researchers, and policymakers, facilitating improved fruit production practices and contributing to sustainable agricultural development. By offering a detailed analysis of how various attributes interact and affect fruit quality, this research seeks to enhance the understanding of ber fruit physiology and inform strategies for effective post-harvest management.

2. MATERIALS AND METHODS

2.1 Study Area and Treatment Application

The research was carried out at the Department of Horticulture, Sri Karan Narendra Agriculture University, Jobner, Rajasthan in February 2019-20. In this experiment used the various post-harvest treatments for the evaluation of effect on physico-biochemical parameters of ber fruit during ambient storage condition.

Evenly sized uniform ripened fruits of ber cultivar Umran were procured on 25th February 2019 at the peak maturity period from Krishi Vigyan Kendra, Ajmer under S.K.N. Agriculture University, Jobner, Jaipur. The fruits were wash with tap water and then treated with different concentrations of post-harvest chemicals after the initial physico-chemical analysis. The fruits treated with various treatments in an aqueous solution, namely $CaCl_2$ (0.5, 1.0 and 1.5%) and GA_3 (20, 40 and 60ppm) for a duration of five minutes at ambient temperature. The treated fruits were then dried in a shady location, placed in Netlon bags, and stored in a room with average temperature and humidity levels (9.8-34.2°C and 60-88% relative humidity). The experiment was carried out using a completely randomized design, consisting of seven treatments and replicated three times. Each replication comprised a quantity of fruit weighing one kilogram.

2.2 Evaluation of Fruit Properties

The physiological weight loss and decay loss were computed using the formula proposed by Srivastava and Tandon [17].

$$\text{PLW (\%)} = \frac{\text{Initial weight (g)} - \text{ final weight (g)}}{\text{Initial weight (g)}} \times 100$$

$$\text{Decay loss (\%)} =$$

$$\frac{\text{Weight of decayed fruit (g)}}{\text{Initial weight of fruits at the time of packing (g)}} \times 100$$

The marketability of fruits was determined as a percentage using following formula;

$$\text{Marketability (\%)} = 100 - \text{\% Decay fruits}$$

The fruit weight was recorded using an electronic balance and the average weight was computed by dividing the total weight (gram) of the fruits by the number of fruits. The pulp weight (g) of individual fruit was calculated by subtracting the weight of stone from the weight of the whole fruit. The fruit juice was uase to analysis of total soluble solids content and it was measured in ºBrix, using a hand refractometer AOAC [18]. The fruit's titratable acidity noted as percentage and it was measured by titrating the fruit juice sample with a standardized solution of 0.1 N sodium hydroxide, using phenolphthalein as an indicator [18]. The ascorbic acid content in the fruit measured in mg per 100 g, was determined by titrating the juice with a solution of 2,6-

dichlorophenol indophenol dye until it achieved a pale pink colour [19]. The quantification of total sugars (%) was conducted using the Lane and Eynon method, as described by Ranganna [20].

2.3 Data analysis

The Pearson correlation coefficient (r) was used to calculate the linear association between fruit weight and various physico-chemical attributes on 9th day after storage. The MS-Office Excel software was utilized to compute the simple correlation matrix described by Snedecor and Cochran [21].

Simple linear regression (SLR) is a statistical technique performed to examine the correlation between an explanatory variable (independent) and a response variable (dependent) by fitting a linear equation to the observed data on the 9th day after storage [22]. The model for Simple Linear Regression (SLR) is as follows:

$$Y = \beta_o + \beta_1 X + \epsilon$$

Where, Y is the dependent variable; X is the independent variable; β_0 is an intercept (the value of Y when X=0); β_1 is the slope of the regression line (the change in Y for a one-unit change in X); ϵ represents the error term. In the present study, SPSS ver. 15 (Cary, NC., USA) was used to calculate the correlation and simple linear regression.

3. RESULTS AND DISCUSSION

3.1 Correlation Matrix between Fruit Weight and Physico-biochemical Attributes

The degree of linear correlation between fruit weight and various attributes (physiological loss in weight, decay loss, marketability, pulp content, total soluble solids, titratable acidity, ascorbic acid, and total sugars) are presented in the correlation matrix (Table 1). The analysis of the Pearson's correlation matrix reveals significant correlations into the fruit weight (FW) and other physico-chemical components of ber under ambient storage condition.

Fruit weight is strongly positively correlated with marketability (r = 0.953), pulp content (r = 0.847), total soluble solids (r = 0.931), titratable acidity (r = 0.961), ascorbic acid (r = 0.984) and total sugars (r = 0.961). This indicated that heavier fruits tend to have more marketability, pulp content, higher soluble solids (which can enhance sweetness and flavor), increased acidity (potentially affecting taste and preservation quality), and higher vitamin C content, reflecting nutritional value. These attributes make larger fruits more marketable and nutritionally superior. Conversely, fruit weight is negatively correlated with physiological loss in weight (r = -0.943) and decay loss (r = -0.953). This suggests that heavier fruits experience less weight loss and decay, maintaining better firmness and quality during storage, thus extending shelf life and commercial appeal.

The strong correlations between fruit weight and both titratable acidity and ascorbic acid suggest that larger fruits have higher acidity and vitamin C levels, which are critical for nutritional value and storage stability. Additionally, the inverse correlation between fruit weight and physiological loss in weight indicated that larger fruits retain more moisture and experience less shrinkage, contributing to their longer shelf life and consumer attractiveness. In summary, the significant associations between fruit weight and various physico-biochemical attributes highlight the importance of selecting heavier fruits for improved quality, including increased sweetness, acidity, vitamin C content, and reduced weight loss during storage. These factors collectively enhance the marketability and storage viability of ber fruits [23,24]. Similar trends have been observed in other fruit crops like guava [25], mango [26], and apple [27], where heavier fruits often exhibit superior quality attributes such as increased sweetness, acidity, and vitamin C content. In guava, for instance, larger fruits have been found to have higher TSS and vitamin C content, which contribute to better flavor and nutritional quality [28]. The negative correlations between fruit weight and physiological loss in weight (PLW) and decay loss observed in ber align with findings in fruits like banana, where heavier fruits show lower weight loss and decay during storage [29].

Table 1. Pearson's correlation matrix for physico-chemical components of ber under ambient storage condition

	PLW	DL	MARK	P	TSS	TA	AA	TS	FW
PLW	1								
DL	0.806**	1							
MARK	-0.806**	-1.000**	1						
P	-0.822**	-0.775**	0.775**	1					
TSS	-0.938**	-0.860**	0.860**	0.667**	1				
TA	-0.966**	-0.871**	0.871**	0.895**	0.887**	1			
AA	-0.952**	-0.920**	0.920**	0.880**	0.898**	0.991**	1		
TS	-0.964**	-0.885**	0.885**	0.742**	0.994**	0.929**	0.938**	1	
FW	-0.943**	-0.953**	0.953**	0.847**	0.931**	0.961**	0.984**	0.961**	1

*Note: PLW, physiological loss in weight; DL, decay loss; MARK, marketability; P, pulp content; TSS, total soluble solids; TA, titratable acidity; AA, ascorbic acid; TS, total sugars; FW; fruit weight. Correlation values followed by * indicates the significance of correlation at p = .05 probability level and correlation values followed by ** indicate significance at p = .01; NS: not significant*

Table 2. Pearson correlation coefficient (r), coefficient of determination (r^2), linear regression equation (y) and significance of the relationship (p) between dependent and independent variables

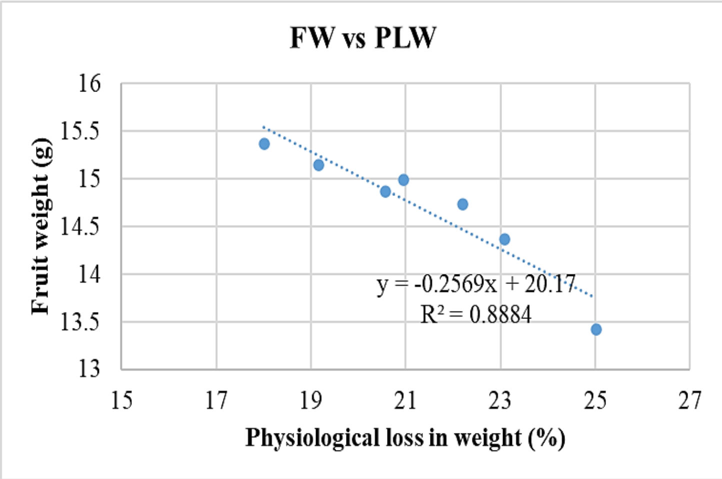
Variables	r =	r^2 =	y =	p =
FW vs PLW	-0.943	0.888	-0.257x + 20.17	.01
FW vs DL	-0.953	0.909	-0.161x + 17.89	.01
FW vs MARK	0.953	0.909	0.162x + 1.81	.01
FW vs P	0.847	0.718	0.179x - 0.87	.01
FW vs TSS	0.931	0.867	0.719x + 4.62	.01
FW vs TA	0.961	0.923	24.893x + 10.15	.01
FW vs AA	0.984	0.968	0.078x + 8.82	.01
FW vs TS	0.961	0.923	0.443x + 9.76	.01

Note: *Depended variable is fruit weight (FW) and independent are physiological weight in loss (PLW), decay loss (DL), marketability (MARK), pulp content (P), total soluble solids (TSS), titratable acidity (TA), ascorbic acid (AA) and total sugars (TS) for post-harvest treatment stored at ambient storage condition*

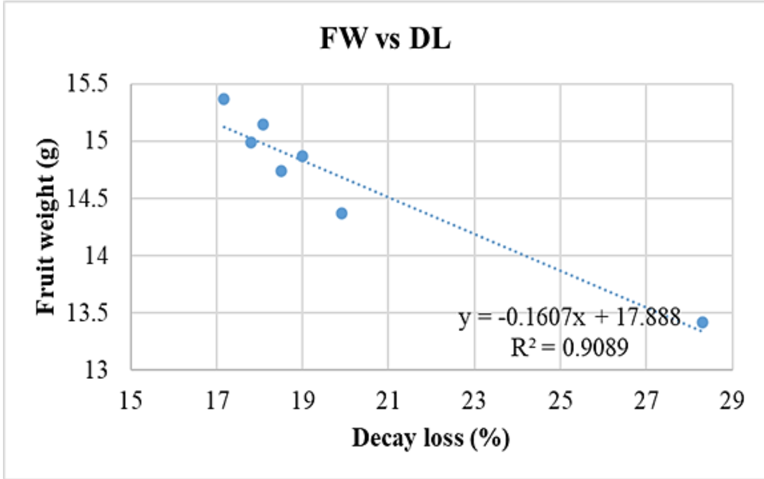
3.2 Simple Linear Regression Analysis

Simple linear regression analysis was performed by using the fruit weight (g) as a dependent variable and the remaining variables as independent variables. The correlation matrix (Table 1) showed a significant correlation among independent variables, which generates a multicollinearity problem. Simple linear regression avoids the issue of multicollinearity since it only involves a single predictor value. A linear regression model was applied to all datasets and thus the following equation was used to summarize the relationship between variables: [$y = ax + b$]; where y = dependent quantitative attribute and x = independent attributes (Table 2). Graphic representations were shown only for those relationships in which r or $r^2 \geq 0.7$ and $p < 0.01$ (Fig. 1a-h). The analysis of the Pearson correlation coefficients (r), coefficient of determination (r^2), linear regression equations (y) and the significance of relationships (p) between subjective fruit weight and various post-harvest quality parameters stored at ambient conditions reveals several findings in ber (Table 2 and Fig. 1a-h).

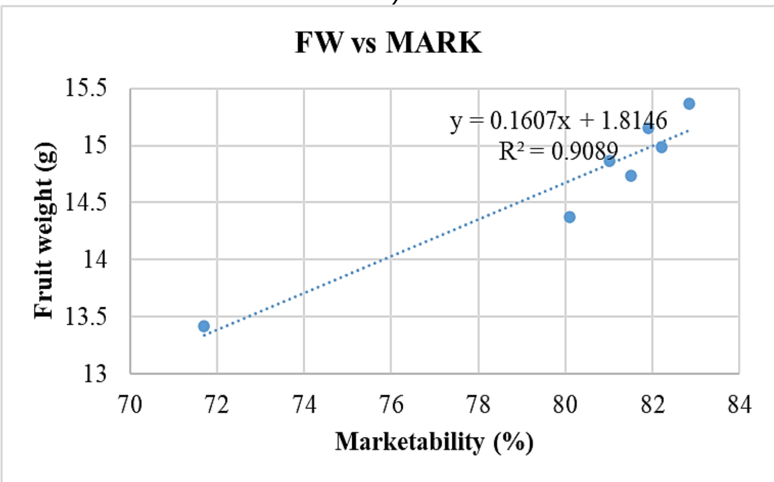
The negative correlation between fruit weight (FW) and physiological loss in weight (PLW) ($r = -0.943$, $p = .01$) and decay loss (DL) ($r = -0.953$, $p = .01$) indicated that as the physiological loss in weight and decay loss increases, the fruit weight decreases significantly. The coefficient of determination ($r^2 = 0.888$) suggests that approximately 88.8% of the variation in PLW can be explained by changes in FW. The regression equation $y = -0.257x + 20.17$ further supports this inverse relationship (Fig. 1a). In case of decay loss, the coefficient of determination ($r^2 = 0.909$) suggests that approximately 90.9% of the variation in DL can be explained by changes in FW. The regression equation $y = -0.161x + 17.89$ further supports this inverse relationship (Fig. 1b).


FW vs PLW
Fruit weight (g)
16
15.5
15
14.5
14
13.5
13
15
17
19
21
23
25
27
y = -0.2569x + 20.17
R² = 0.8884
Physiological loss in weight (%)

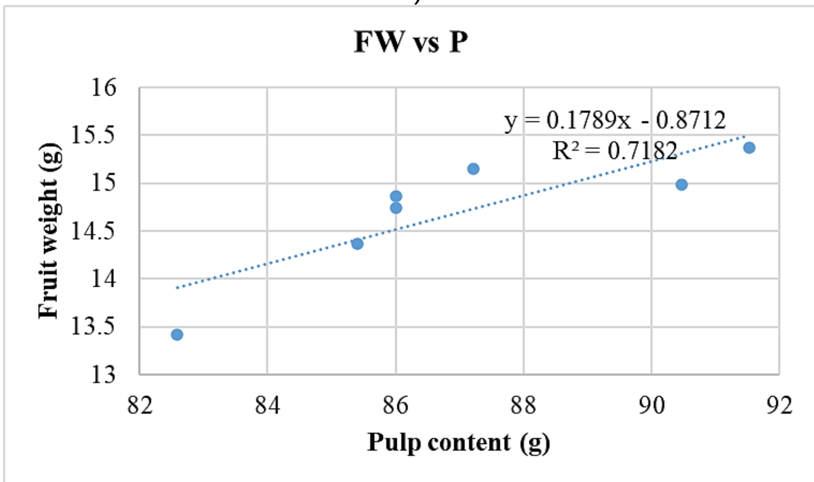
a)


FW vs DL
Fruit weight (g)
15.5
15
14.5
14
13.5
13
15
17
19
21
23
25
27
29
y = -0.1607x + 17.888
R² = 0.9089
Decay loss (%)

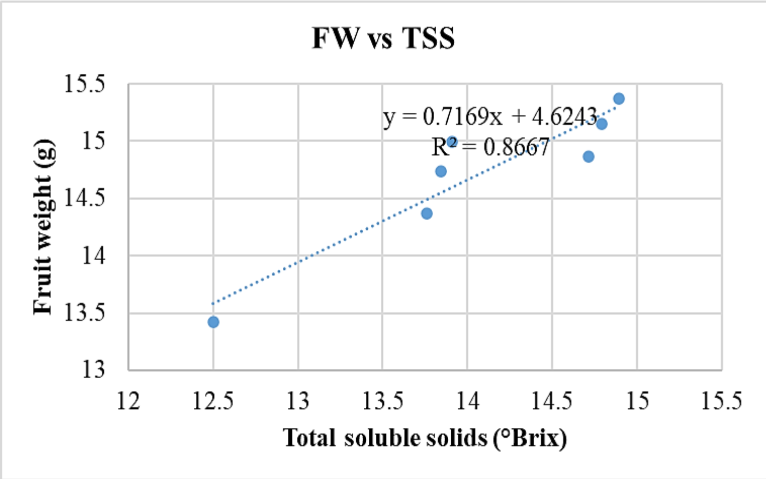
b)


FW vs MARK
Fruit weight (g)
15.5
15
14.5
14
13.5
13
70
72
74
76
78
80
82
84
y = 0.1607x + 1.8146
R² = 0.9089
Marketability (%)

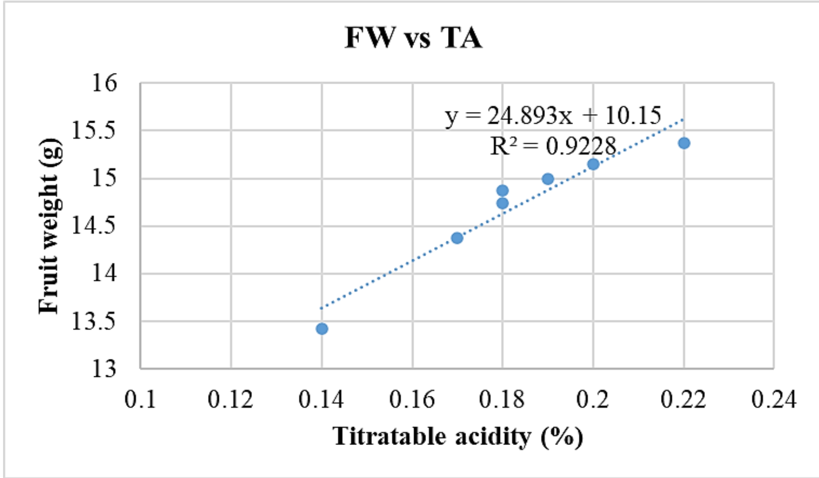
c)


FW vs P
Fruit weight (g)
16
15.5
15
14.5
14
13.5
13
82
84
86
88
90
92
y = 0.1789x - 0.8712
R² = 0.7182
Pulp content (g)

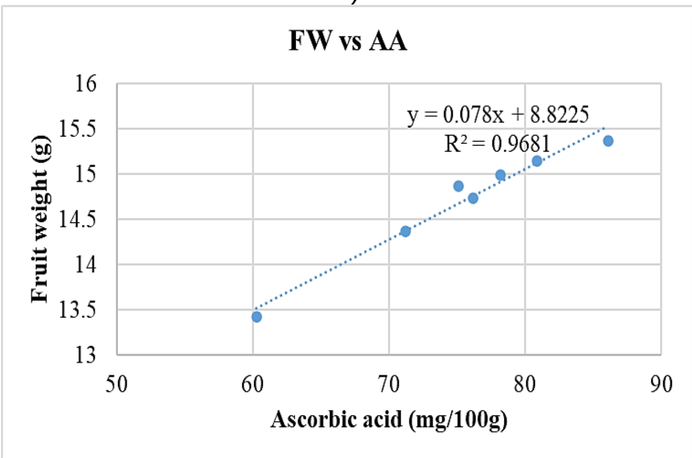
d)



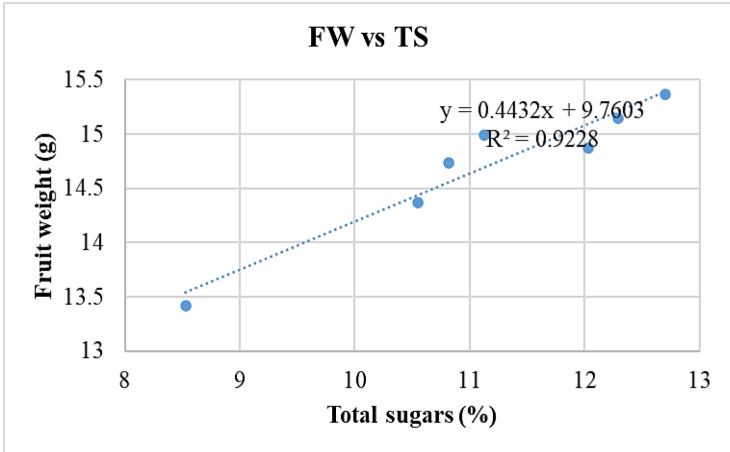
e)



f)



g)



h)

Fig. 1a-h. Scatter plots and linear regression lines showing the relationship between subjective fruit weight and physiological loss in weight (a), decay loss (b), marketability (c), pulp content (d), total soluble solids (e), titratable acidity (f), ascorbic acid (g) and total sugars (h) for ber

While, strong positive correlation was observed between Fruit weight (FW) with marketability (0.953), pulp content (0.847), total soluble solids (0.931), titratable acidity (0.961), ascorbic acid (0.984) and total sugars (0.961), all of which are highly significant ($p = 0.01$). These strong correlations suggest that an increase in fruit weight is associated with an increase in these quality parameters and leads to high marketability. The corresponding coefficients of determination (r^2) for these relationships range from 0.717 to 0.968, indicating a high level of explanation for the variation in these parameters by fruit weight.

The linear regression equations for these relationships, such as $y = 0.162x + 1.81$ for marketability, $y = 0.179x - 0.87$ for pulp content, $y = 0.717x + 4.62$ for total soluble solids, $y = 0.717x + 4.62$ for titratable acidity, $y = 0.078x + 8.82$ for ascorbic acid and $y = 0.443x + 9.76$ for total sugars, showed that as fruit weight increases, these physical and quality attributes also increase proportionally. Overall, the results indicated a significant and robust relationship between fruit weight and the measured quality parameters during post-harvest storage, with implications for improving storage practices and fruit quality management.

4. CONCLUSION

The study effectively determined the correlation and simple linear regression analysis to establish the relationships between fruit weight and other physico-biochemical parameters of Indian jujube (*Ziziphus mauritiana* Lamk.) cv. Umran during the ambient storage. The findings indicated a strong positive relationship between fruit weight and the physical and biochemical criteria of marketability, pulp, total soluble solids, titratable acidity, ascorbic acid and total sugars. This suggests that when the fruit weight increased, these attributes also improve. A strong negative association was found between fruit weight and physiological loss in weight and decay loss indicated that as fruits undergo physiological processes that cause weight loss, their overall fruit weight declines. The linear regression models provided additional evidence for these correlations, showing that differences in fruit weight can account for a significant percentage of the variability in the quality indices examined. This study offers a scientific basis for enhancing storage conditions and optimising post-harvest treatments to improve the quality characteristics in Indian jujube fruits. This, in turn, leads to increased marketability of the fruits and more satisfaction among consumers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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