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Association between Physico Biochemical Parameters of Ber (*Ziziphus mauritiana* Lamk.) cv. Umran under Cold 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 examine the relationship between the physical and biochemical attributes of Indian jujube or ber (*Ziziphus mauritiana* Lamk.) cultivar Umran, affected by treatments applied after harvest and stored under cold storage conditions.

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Place and Duration: This investigation was conducted at Horticulture Department of SKN Agriculture University, Jobner in the month of February to March, 2019.

Methodology: The fruits treated with calcium chloride ($CaCl_2$) (0.5, 1.0 and 1.5%) and gibberellic acid (GA_3) (20, 40 and 60ppm) while being maintained in cold storage. The experiment was carried out utilizing a Completely Randomized Design (CRD), consisting of seven treatments and three replications. The study evaluated multiple attributes of fruits, such as physiological weight loss, marketability, pulp percentage, total soluble solids, titratable acidity, ascorbic acid, total sugars and reducing sugars.

Results: The correlation analysis revealed a highly significant positive correlation between the weight of the fruit and various quality measures, such as marketability (r = 0.959), pulp percent (r =0.846), total soluble solids (r =0.947), titratable acidity (r =0.998), ascorbic acid (r =0.991), total sugars (r =0.980) and reducing sugars (r =0.963). While, a strong negative association was observed between the fruit's weight and PLW (r =-0.947). The linear regression model provides additional evidence for this relationship revealed that changes in fruit weight were responsible for a substantial amount of the differences observed in the evaluated quality attributes. The values of the coefficients of determination (r^2) varied between 0.747 and 0.996.

Conclusion: The strong correlations and regression model provide valuable insights for improving post-harvest handling and storage practices, leading to enhanced preservation of fruit quality during cold storage.

Keywords: Correlation; linear regression; cold storage; Ziziphus; quality.

1. INTRODUCTION

The ber (*Ziziphus mauritiana* Lamk.) is a mostly grown fruit in India and China. It is a member of the Rhamanaceae family. It is generally known as the fruit of the economically underprivileged. The fruit is ideally suited for cultivation in arid and semi-arid regions of Northern India. Ber cultivation is popular in several states of India i.e., Gujarat, Rajasthan, Madhya Pradesh, Haryana, Punjab, Bihar, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, West Bengal and Assam [1]. India has ber crop area is approximately 47.92 thousand hectares, with a yearly output of 512.03 thousand metric tons [2]. The cultivation of ber in Rajasthan covers an area of around 1.11 thousand hectares, resulting in an annual yield of 9.59 thousand metric tons [2]. The ber is quite nourishing and health beneficial. The fruit's pulp contains almost 13-19% total soluble solids (T.S.S.) and 0.20 to 0.60% acidity when fully ripe. The berries of the ber tree are an exceptionally rich source of vitamin C, ranking only below anola and guava in terms of concentration. In addition, it has a substantial protein content of 0.8g per 100g, along with minerals such as phosphorus (0.148%) and iron (0.54%) [3]. The ber pulp contains the amino acids asparagine, aspartic acid, arginine, glutamic acid, serine, glycine, threonine, α-alanine, valine, methionine, leucine and isoleucine [4]. Ber fruits have lower shelf life and cannot be stored for a long time under ambient storage conditions [5]. Ensuring the long-term aroma and flavour of perishable fruits after they have been harvested is a critical factor in how they are managed and stored. Various methods have been used to preserve the quality of fruits post-harvest. In view of these methods, use of gibberellins has the capacity to delay the ripening process and act as agents that combat senescence. Gibberellic acid (GA_3) affects the degradation of intricate carbohydrates and the synthesis of sucrose, whereas calcium promotes the softening of maturing [6,7].

Correlation analysis provides information on the strength and direction of association between different physico-biochemical variables. It assists in identifying the characteristics that mutually affect each other in a favorable or negative way, therefore offering recommendations for targeted breeding and management techniques. However, it is important to note that the existence of a correlation does not prove causality. To determine causation, further investigation is necessary, employing advanced statistical methods such linear regression [8,9]. Linear regression is used to analyze the relationship between physico-biochemical features and the overall quality of the fruit. It helps determine the specific impact of each feature on the quality [10]. Regression analysis is a statistical technique used to model and predict complicated interactions. It helps us understand how a response variable, like fruit weight, is influenced by several predictor elements, such as physiological loss in weight, total soluble solids, sugar content, and acidity. This study aims to rectify this inadequacy by conducting an extensive examination of the correlation and linear regression of the physico-biochemical properties of Indian jujube cv. Umran. The objective of this study is to conduct a comprehensive analysis of these characteristics with the purpose of providing practical insights to stakeholders in the agricultural industry, including farmers, researchers and policymakers. This will ultimately facilitate the advancement of sustainable fruit cultivation and foster economic growth.

2. EXPERIMENTAL DETAILS

2.1 Study Area and Treatment Application

This study aimed to analyse the correlation and linear regression between physico-biochemical parameters of Indian jujube or ber cultivar Umran. The investigation was carried out at the Horticulture Department of SKN Agriculture University, Jobner, Rajasthan from month of February to March in the year 2019. This experiment focused on the analysed the associations between physico-biochemical parameters influenced by post-harvest treatments under cold storage condition.

The fruits were washed with tap water and then treated with various concentrations of chemicals after the initial physico-chemical analysis. The fruits were soaked in a water-based solution that included various compounds, i.e., $CaCl_2$ (0.5%, 1.0% and 1.5%) and GA_3 (20ppm, 40ppm and 60ppm) for five minutes at room temperature. The treated fruits were dehydrated in a covered location, then packed in Netlon bags and stored in a cold storage chamber with maintain a temperature range of 4-6°C and a relative humidity of 85-95%. The experiment was carried out utilizing a completely randomized design (CRD), consisting of seven treatments and three replications. Each replication comprised one kilogram of fruit.

2.2 Evaluation of Various Fruit Attributes

The percent of physiological weight loss was determined by comparing the initial weight with the weight at succeeding intervals as computed by Srivastava and Tandon [11]. Whereas, the marketability percentage was calculated using the formula;

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

However, the per cent of pulp was calculated by the using formula mentioned below;

$$\text{Pulp (\%)} = \frac{\text{Total weight of pulp total (g)}}{\text{Total weight of fruit (g)}} \times 100$$

An electronic balance developed by Sartoius in Japan was used to measure the weight of five fruits. The average weight was determined by dividing the total weight of the fruits by the quantity of fruits and expressed in gram. An analysis was done on the fruit juice to determine its total soluble solids content, which was quantified in ºBrix using a handheld refractometer. The results were subsequently calibrated to a temperature of 20°C, in accordance with the protocols proposed by AOAC [12]. The titratable acidity of fruits measured as a percentage was assessed by titrating the juice with a standardized solution of 0.1 N sodium hydroxide using phenolphthalein as an indicator [12]. The concentration of ascorbic acid in the fruit expressed as milligram per 100 gram of fruit weight was assessed by titrating the juice with a solution of 2,6-dichlorophenol indophenol dye until it achieved a faint pink color. The color remained unchanged for a duration of 15 seconds, as indicated by the AOAC [13]. The Lane and Eynon method as described by Ranganna [14] was used for analysed the total and reducing sugars.

2.3 Data Analysis

The Pearson correlation coefficient (r) was used to calculate the straightforward association between fruit weight and various physico-chemical characteristics. The MS-Office Excel software was utilized to compute the simple correlation matrix as described by Snedecor and Cochran [15].

Simple linear regression (SLR) is one of the statistical method which attempts to model the relationship between one interpretive variable (independent) and a response variable (dependent) by fitting a linear equation into the observed data [16]. The model for SLR is:

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

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 is 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 Parameters

The degree of association of the fruit weight with all other variables (PLW, marketability, pulp percentage, total soluble solids, titratable acidity, ascorbic acid, total and reducing sugars) is presented in a correlation matrix (Table 1). The fruit weight positively correlated with the marketability (0.959), pulp percentage (0.864), total soluble solids (0.947), titratable acidity (0.998), ascorbic acid (0.991), total sugars (0.980) and reducing sugars (0.963), while significant negative correlation were reported with the physiological loss in weight (-0.943) during fruit of ber stored under cold storage condition.

The significant correlations between fruit weight and the analysed physico-biochemical properties emphasise the crucial role of fruit weight in ber. The findings indicated that choosing heavier fruits could result in improved fruit quality, including increased sweetness, acidity, vitamin C content and reduced weight loss during storage [17]. This association corresponds to the positive link observed with TSS, as total sugars constitute a fundamental constituent of soluble solids in fruits [18]. The inverse correlation seen between fruit weight and physiological weight loss indicates that bigger fruits are more resistant to weight loss during storage, perhaps because of their increased moisture content and improved water retention. The decreased physiological loss in weight (PLW) in fruits enhances their extended shelf life and commercial viability, hence increasing their attractiveness to customers [19].

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

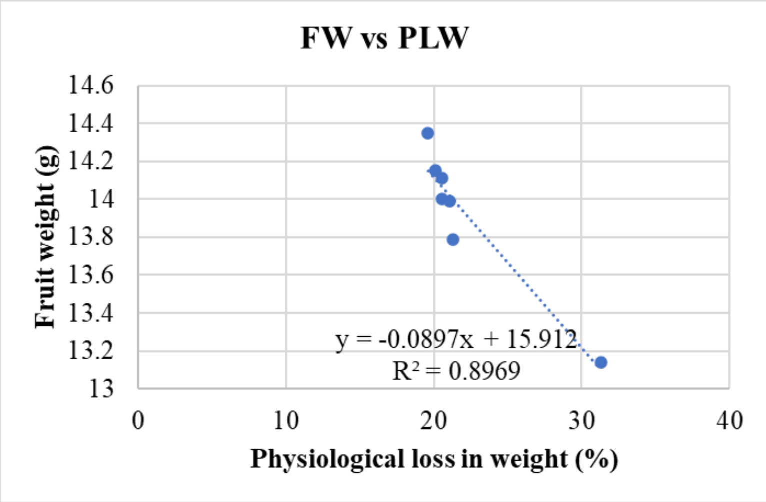
	PLW	MARK	P	TSS	TA	AA	TS	RS	FW
PLW	1								
MARK	-0.994**	1							
P	-0.707**	0.713**	1						
TSS	-0.996**	0.984**	0.730**	1					
TA	-0.953**	0.960**	0.869**	0.954**	1				
AA	-0.899**	0.920**	0.895**	0.902**	0.983**	1			
TS	-0.975**	0.991**	0.770**	0.966**	0.977**	0.956**	1		
RS	-0.946**	0.976**	0.741**	0.929**	0.955**	0.945**	0.992**	1	
FW	-0.947**	0.959**	0.864**	0.947**	0.998**	0.991**	0.980**	0.963**	1

*Note: PLW, physiological loss in weight; MARK, marketability; P, pulp; TSS, total soluble solids; TA, titratable acidity; AA, ascorbic acid; TS, total sugars; RS, reducing 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*

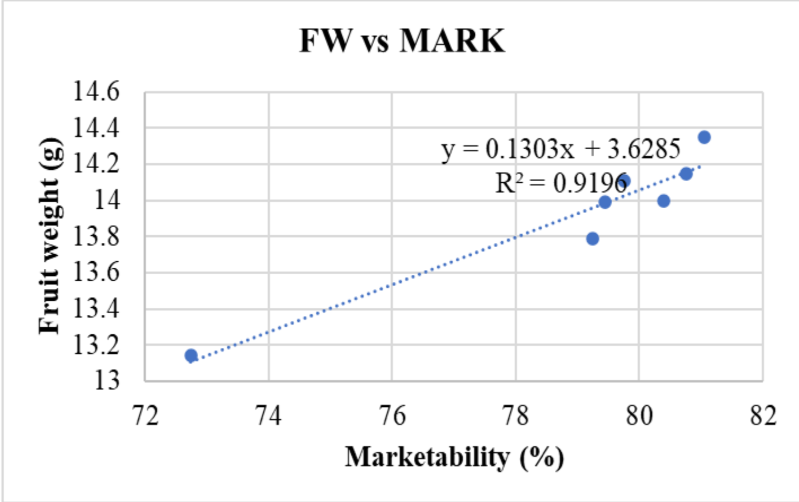
Table 2. Pearson correlation coefficient (r), coefficient of determination (r^2), linear regression equation (y) and significance of the relationship (p) between dependent and independent variables

Variables	r =	r^2 =	y =	p <
FW vs PLW	-0.947	0.897	-0.090x+15.91	.01
FW vs MARK	0.959	0.920	0.130x+3.63	.01
FW vs P	0.864	0.747	0.113x+4.09	.01
FW vs TSS	0.947	0.898	0.257x+10.30	.01
FW vs TA	0.998	0.996	16.977x+11.10	.01
FW vs AA	0.991	0.981	0.055x+9.35	.01
FW vs TS	0.980	0.960	0.315x+10.51	.01
FW vs RS	0.963	0.927	0.530x+10.67	.01

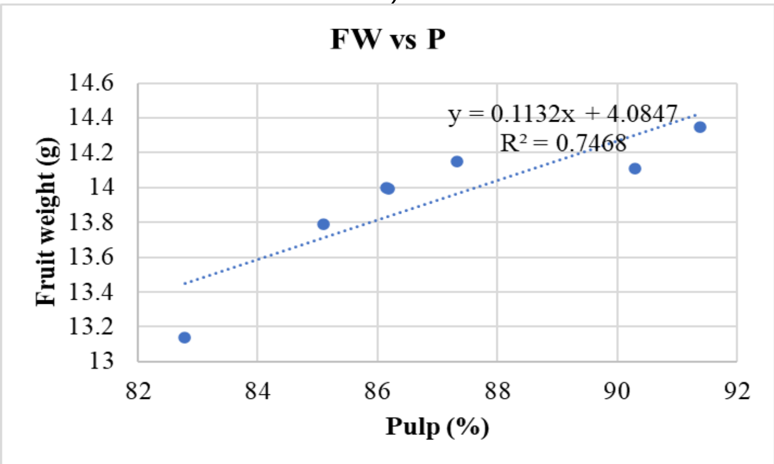
Note: Depended variable is fruit weight (FW) and independent are physiological weight in loss (PLW), marketability (MARK), pulp (P), total soluble solids (TSS), titratable acidity (TA), ascorbic acid (AA), total sugars (TS) and reducing sugars (RS) for post-harvest treatment stored at cold storage condition


FW vs PLW
Fruit weight (g)
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
13
0
10
20
30
40
Physiological loss in weight (%)
y = -0.0897x + 15.912
R² = 0.8969

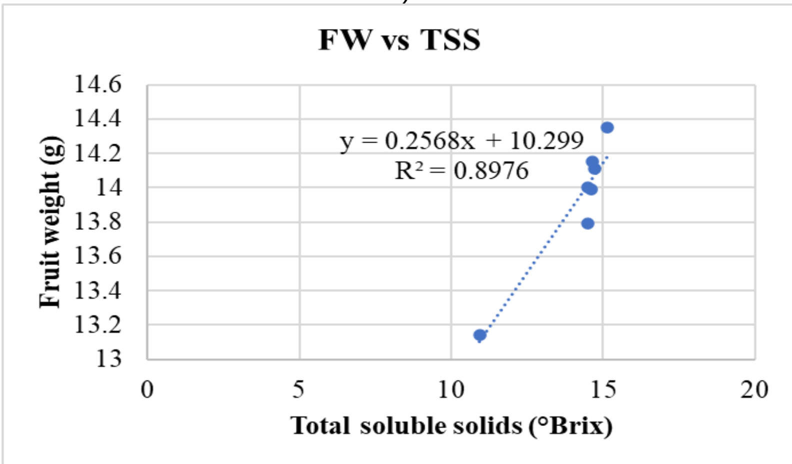
a)


FW vs MARK
Fruit weight (g)
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
13
72
74
76
78
80
82
Marketability (%)
y = 0.1303x + 3.6285
R² = 0.9196

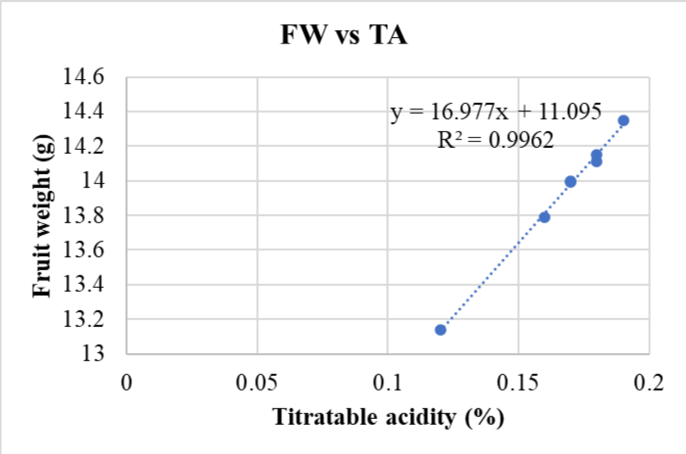
b)


FW vs P
Fruit weight (g)
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
13
82
84
86
88
90
92
Pulp (%)
y = 0.1132x + 4.0847
R² = 0.7468

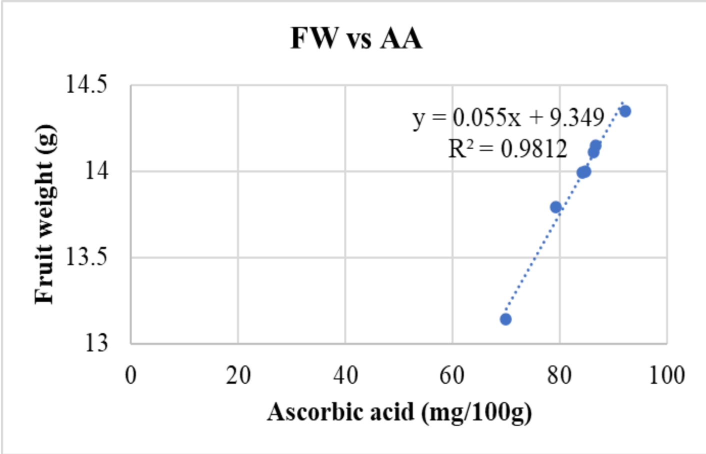
c)


FW vs TSS
Fruit weight (g)
14.6
14.4
14.2
14
13.8
13.6
13.4
13.2
13
0
5
10
15
20
Total soluble solids (°Brix)
y = 0.2568x + 10.299
R² = 0.8976

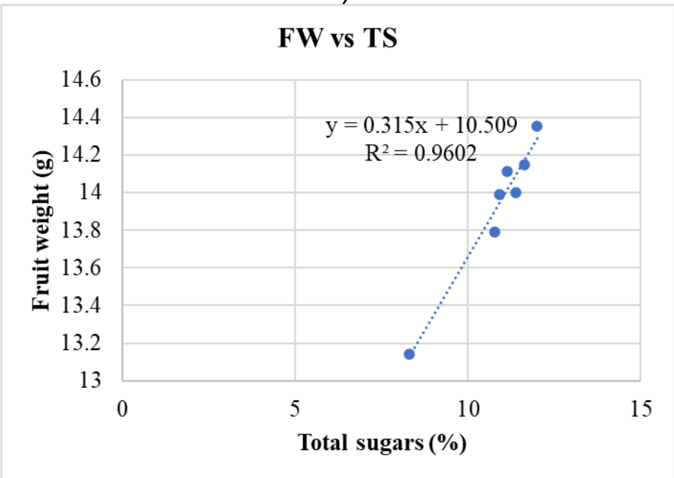
d)



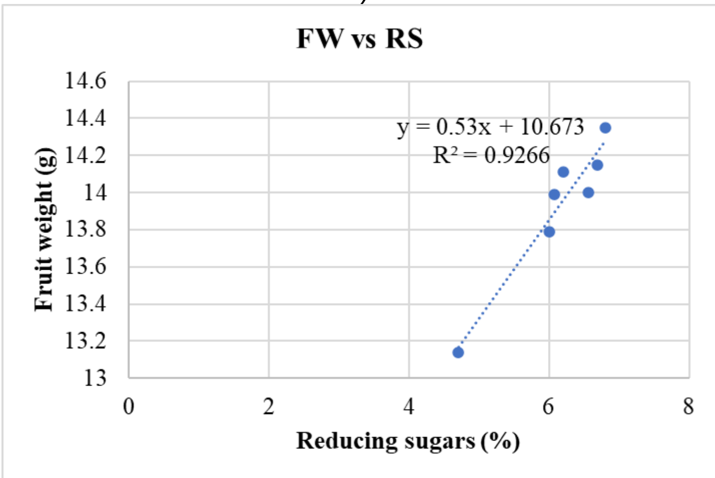
e)



f)



g)



h)

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

3.2 Simple Linear Regression Analysis

Simple linear regression analysis was performed by between the fruit weight (g) selected 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 analysis overcomes the problem of multi collinearity. 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 ≥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 cold condition revealed several findings in ber (Table 2 and Figs. 1a-h).

The negative correlation between fruit weight (FW) and physiological loss in weight (PLW) (r = -0.947, p < 0.01) indicated that as the physiological loss in weight increases the fruit weight decreases significantly. The coefficient of determination (r^2 = 0.897) suggests that approximately 89.7% of the variation in PLW can be explained by changes in fruit weight. The regression equation y = -0.090x+15.91 further supports this inverse relationship (Fig. 1a). However, strong positive correlations were observed between fruit weight (FW) and marketability (MARK), pulp percentage (P), total soluble solids (TSS), titratable acidity (TA), ascorbic acid (AA), total sugars (TS) and reducing sugars (RS) with correlation coefficients of r = 0.959, 0.864, 0.947, 0.998, 0.991, 0.980 and 0.963 respectively, all of which are highly significant. These strong correlations suggest that an increase in fruit weight is associated with an increase in marketability and these quality parameters of ber.

The corresponding coefficients of determination (r^2) for these relationships range from 0.747 to 0.996, indicating a high level of explanation for the variation in these attributes by fruit weight. The linear regression equations for these relationships, such as y = 0.130x+3.63 for marketability, y = 0.113x+4.09 for pulp percentage, y = 0.257x+10.30 for total soluble solids, y = 16.977x+11.10 for titratable acidity, y = 0.055x+9.35 for ascorbic acid, y= 0.315x+10.51 for total sugars and y = 0.53x+10.67 for reducing sugars, showed that as fruit weight increases, these marketability, pulp 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.

The observed correlations between fruit weight and various post-harvest quality parameters for ber align well with studies conducted on other fruit crops [20,21]. The negative correlation between fruit weight and physiological loss in weight (PLW) is a common finding across various fruits. For example, in mango a similar inverse relationship between fruit weight and PLW has been reported, where increased water loss due to respiration and transpiration during storage leads to a marked reduction in fruit weight [22]. The positive correlation observed between fruit weight and marketability in ber can also be seen in apple [23], where increased fruit weight is strongly associated with enhanced marketability due to the visual appeal and consumer preference for larger fruits.

Furthermore, the significant positive correlations between fruit weight and quality attributes such as total soluble solids, titratable acidity and ascorbic acid reflect similar trends seen in citrus fruits like Eureka lemon [24] and lemon [25]. In these crops, heavier fruits generally exhibit higher levels of TSS, acidity and vitamin C content, which are critical parameters for determining fruit flavor and nutritional quality. These correlations indicate that enhancing or preserving fruit weight during post-harvest storage can directly impact the overall sensory quality of the fruit. The regression models predicting the relationship between fruit weight and total sugars, reducing sugars, and pulp percentage in ber are consistent with findings in guava [26] and papaya [27]. In these fruits, an increase in fruit weight typically correlates with a rise in sugar content and pulp, both of which contribute to better taste and texture. Such outcomes are crucial for optimizing post-harvest treatments aimed at maintaining or improving sweetness and juiciness, which are highly valued by consumers.

4. CONCLUSION

The study successfully analysed simple linear regression to establish the associations between the weight of Indian jujube fruits (*Ziziphus mauritiana* Lamk.) cultivar Umran and other physico-biochemical parameters during stored under cold condition. The findings revealed a robust positive correlation between the fruit weight with its market value, pulp percentage and quality parameters i.e., total soluble solids, titratable acidity, ascorbic acid, total and reducing sugars. This implies that when the fruit weight increases, there is also an enhancement in these quality indicators. An inverse correlation was observed between fruit weight and physiological weight loss, suggesting that as fruits undergo physiological processes leading to weight loss, their overall fruit weight decreases. The linear regression models further supported these associations, demonstrated that variations in fruit weight can explain a substantial proportion of the variability in the evaluated quality indices. This study provides a scientific basis for improving storage strategies and optimizing post-harvest treatments to enhance the preservation of qualitative features in Indian jujube fruits while stored in cold condition.

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 manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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