

Original Research Article

Correlation and Linear Regression Study between Physico-Biochemical Attributes of Ber cv. Umran under Ambient Storage

Comment [M1]:

Comment [M2]: Please include the scientific name in brackets after the Ber (*Ziziphus mauritiana*)

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.

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. The study evaluated multiple attributes of the fruit, such as physiological weight loss, decay loss, marketability, pulp content, 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 offer useful insights for enhancing post-harvest handling and storage techniques, ultimately resulting in improved preservation of fruit quality during ambient storage.

Comment [M3]: Please be specific and group the physical and biochemical properties: The physical attributes evaluated include.... and the biochemical attributes were.....

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 is belonging 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 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

Comment [M4]: Or it can be stated with strong emphasis as : The robust correlations and regression models inform evidence-based storage techniques, reducing fruit quality losses during ambient storage.

Comment [M5]: It belongs to....(grammer)

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 to aonla and guava among fruits, making it a critical component of dietary vitamin C intake. Furthermore, ber contain a good amount of protein (0.8g100g⁻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 (GA₃) to delay ripening and reduce senescence. GA₃ 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 CaCl₂[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].

Comment [M6]: Grammer: after guava and.....

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. Umrán. 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. MATERIAL AND METHODS

2.1 Study area and treatment application

The objective of this study was to examine the correlation and linear regression among the physico-biochemical characteristics of the Indian jujube cultivar Umran. 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 post-harvest treatments for the effect on physico-biochemical parameters of ber fruit under ambient storage conditions.

The fruits were clean with tap water and then treated with different concentrations of post-harvest chemicals after the initial physico-chemical analysis. The fruits underwent treatment in an aqueous solution including several chemicals, 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 processed 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].

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

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

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 examined to analysis of total soluble solids content measured in °Brix, using a hand refractometer AOAC [18]. The fruit's titratable acidity recorded as a percentage and it was measured by titrating the juice 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 straightforward association between fruit weight and various physico-chemical attributes at 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

Comment [M7]: This statement should be omitted from this section because it is not recommended to state the objectives at the beginning of the Materials and Methods section for the following reasons:

1. Logical flow; because typically the objective and aims of the study are clearly outlined in the introduction section-the authors have done that already!
2. Materials and Methods focusses on methodology; materials, procedures, techniques, experimental design

Comment [M8]: Grammatical error here

Comment [M9]: Where were the fruits obtained from? or Source of fruits? In an orchard or Market? If in an orchard is there any cultivation history?; the maturity stage, stage of ripeness(e.g. matured unripe, ripe, etc.; What are the selection criteria for the fruits if applicable?

Comment [M10]: Cleaned ; pls kindly check petty grammatical errors

Comment [M11]: An active voice would make the sentence clear; please consider using an active sentence. Eg.' We treated the fruits in an aqueous solution containing.....

Comment [M12]: Please I suggest the term processed be changed to treated because although treated can be termed processed there are subtle differences; Processing refers to any series of operations that transforms raw materials like fruits into products with added value In the context of this write-up, treated is recommended because, Treated often implies a specific action or intervention, e.g., chemical treatment, whereas processed is a broader term that denotes a more significant transformational change of the raw material.; hence treated# is more of a superficial alteration.

Comment [M13]: Check for clarity!!

Comment [M14]: Check for clarity pls.

Comment [M15]: Straightforward association is a bit unclear; instead use 'linear association' to specify the type of relationship being measured.

Comment [M16]: Use 'on' to make it clear

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.

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 analysis overcomes the problem of multicollinearity. 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 (Tables 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 Figs. 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).

Table 2: Pearson correlation coefficient (r), coefficient of determination (r²), 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

Comment [M21]: It is incorrect to state that simple linear regression (SLR) overcomes multicollinearity (kindly give the reference for that statement);

infact it is more susceptible to multicollinearity because SLR has only one predictor variable and multicollinearity can occur in SLR if the predictor variable is highly correlated with other variables not included in the model

However, SLR has an advantage in that it is less likely to suffer from multicollinearity compared to multiple linear regression (MLR) which involves multiple predictor variables

I suggest the statement is rephrased as; Simple linear regression avoids the issue of multicollinearity since it only involves a single predictor value.

OR

Multicollinearity is not a concern in this simple linear regression model as it only includes one predictor variable.

Notwithstanding, the simplicity of SLR can sometimes be a limitation when dealing with complex relationships or multiple predictor variables. In such cases, more advanced regression techniques (there are about 10 depending on the data one can choose the appropriate technique) such as Ridge regression (a regularisation technique that reduces multicollinearity), lasso (L1 regularisation) and Principal component Analysis (a dimensionality reduction technique that overcomes multicollinearity) can be used when appropriate.

In the context of this study FW the dependent variable is strongly correlated with eight predictor values, hence, the regularisation technique specifically, **ridge regression** is recommended because:

Ridge regression handles strong correlations, retains all variables, reduces coefficient estimates and ensures model stability by reducing the variance of coefficient estimates.

Comment [M22]: Please check, multicollinearity is a joint word as written earlier.

Comment [M23]: Please, it is important to note that if a study uses SLR for each predictor variable separately, without addressing multicollinearity, the results should be interpreted with caution.

Although it is not a deal-breaker for publication, it is essential to acknowledge the limitations and potential biases such as the overestimation of effects, lack of control for confounding variables and the inability to assess joint effects.

To make the study more robust, rigorous and excellent scientific work for publication, considering the regularisation technique, ridge regression. This will increase the credibility and impact of the research.

These results can be published, but the authors must clearly discuss limitations and potential biases due to multicollinearity in the manuscript.

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.

While, strong positive correlation was observed between FW and marketability (MARK), pulp content (P), total soluble solids (TSS), titratable acidity (TA), ascorbic acid (AA) and total sugars (TS), with correlation coefficients of $r = 0.953, 0.847, 0.931, 0.961, 0.984$ and 0.961 respectively, 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.

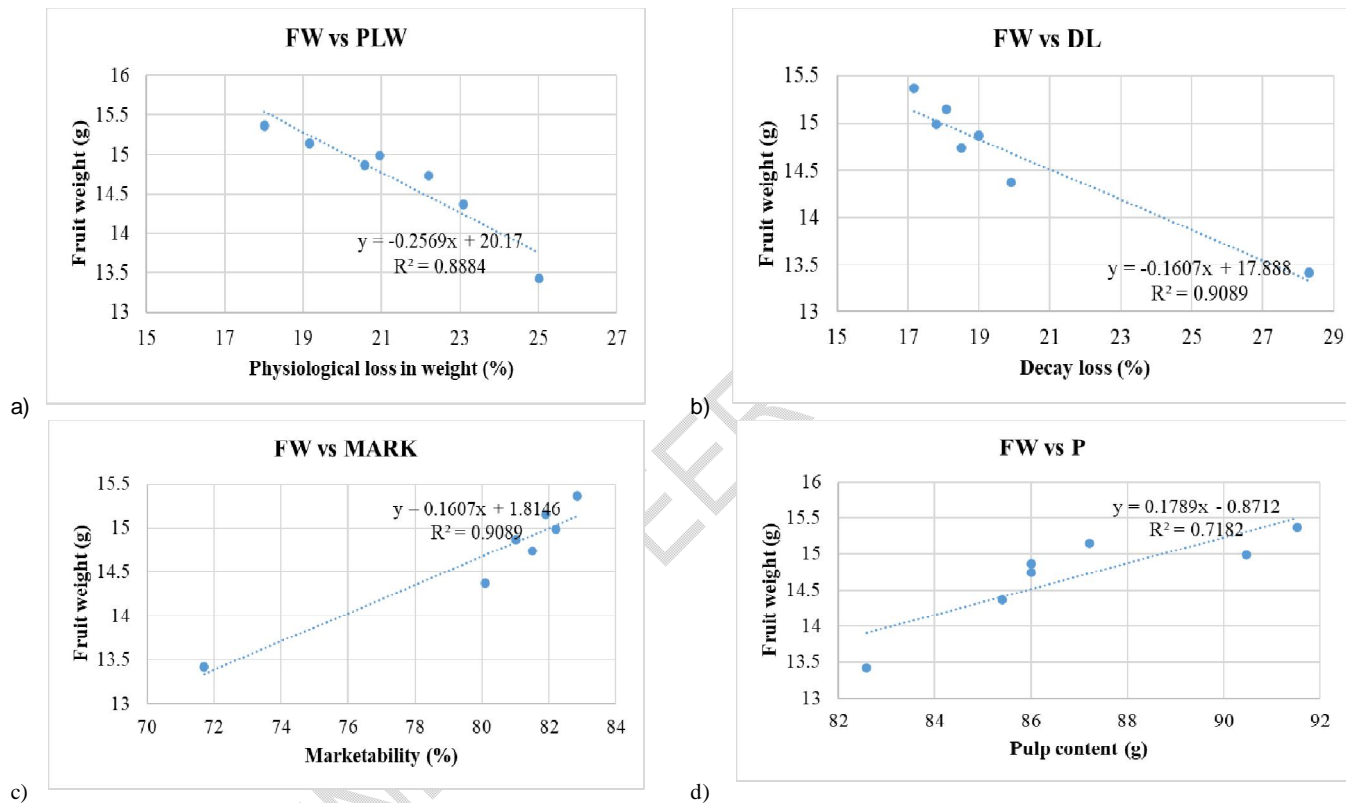
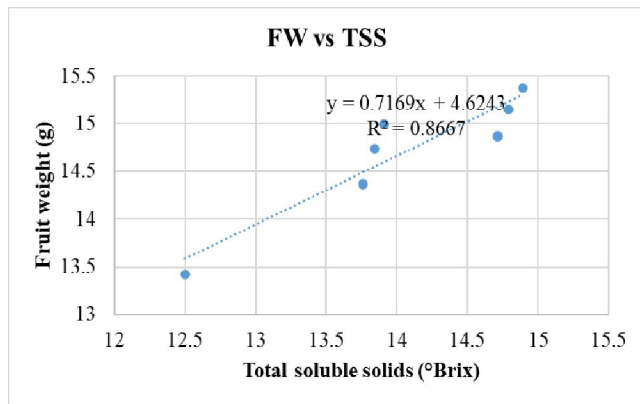
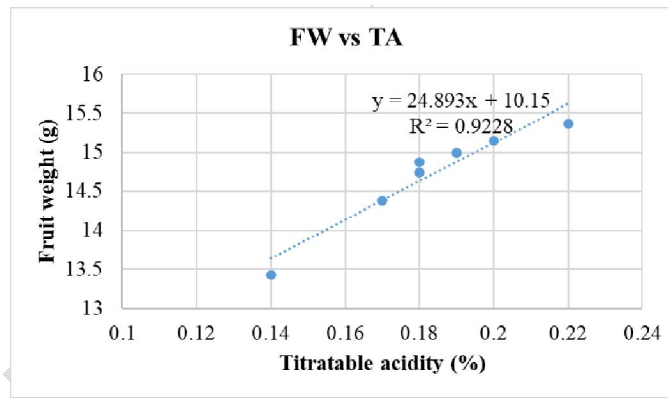


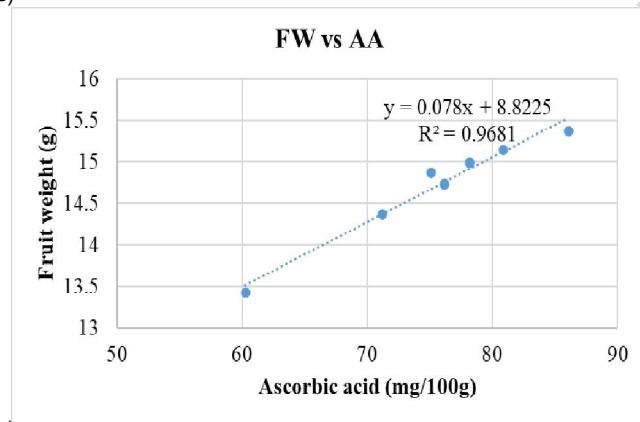
Fig. 1a-h. Scatter plots and linear egression lines showing the relationship between subjective fruit weight and physiological loss in weight (a), decay loss (b), marketability (c), pulp content (d), total soluble solids (e), titratable acidity (f), ascorbic acid (g) and total sugars (h) for ber.



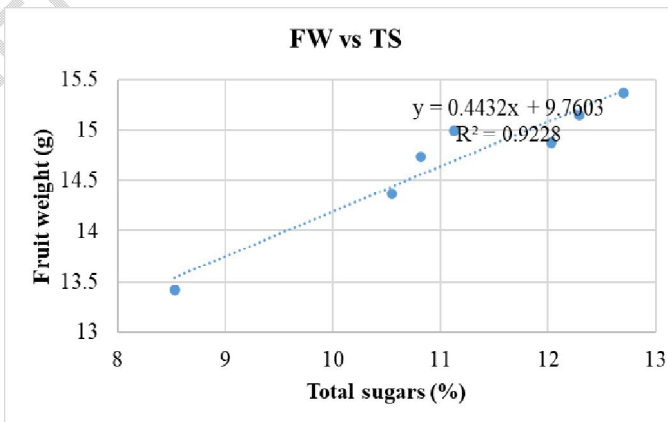
e)



f)



g)



h)

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 quality 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.

Comment [M24]: What about the chemical attributes? are they the same as the quality attributes, please be consistent.

CONSENT

This paper represents original work and has not been previously published elsewhere. All authors listed have contributed significantly to the research and agree to its publication.

ETHICAL APPROVAL

The data presented in this paper is original and has not been published elsewhere.

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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