Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 12 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

Innovations in Date Fruit Processing and Pre-Harvest Marketing: A Review of Drying Technologies, Packaging, and Contract-Based Market Mechanisms

Muhammad Huzaifa
Institute of Food Science and Nutrition, Gomal University.
huzaifa.fst@yahoo.com

Naveed Ahmad Khan
Institute of Food Science and Nutrition, Gomal University.
naveed.sumbalstar@gmail.com

Tooba Gull
Institute of Food Science and Nutrition, Gomal University.
toobagull30@gmail.com

Muhammad Abbas Dilawar
Institute of Food Science and Nutrition, Gomal University.
abbasdilawar1@gmail.com

Muhammad Abdullah
Department of Chemistry, Thal University Bhakkar.
abdullah.chemtt@gmail.com

ABSTRACT

The date palm (*Phoenix dactylifera* L.) is a significant source of livelihood in the arid and semi-arid areas of Pakistan, especially the Sindh, Balochistan and southern part of Khyber Pakhtunkhwa. The Pakistani date value chain is facing heavy post-harvest losses (PHL) despite the growth in production and export potentials because of ineffective drying practices, poor packaging, and poor coordination in the market. The review summarizes peer-reviewed, published articles between 2019 and 2024 to assess technological progress in date fruit processing-that is, drying and packaging-and to determine the novel application of contract-based and digital pre-harvest marketing

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systems. A strategic search on Google Scholar was conducted, which revealed 52 related studies, and 22 of these were eligible to fulfil the inclusion criteria. The post-harvest losses in the traditional smallholder-dominated supply chains have been reported, on average, to be 25% to above 40% and the harvesting and drying processes incur the highest proportion of losses in Pakistan. Drying methods such as solar-assisted and hot-air drying systems (regulated drying methods) always had reduced final moisture content and quicker drying rates than open sun drying, positively influencing product stability. Innovations in packaging especially vacuum sealing and modified atmosphere packaging have provided a big extension of storage under controlled conditions. Horticultural crop evidence, especially in Pakistan and other similar areas, indicates that post-harvest loss and farmer income could be enhanced by the use of contract-based marketing agreements to enhance coordination and quality incentives; although there is a lack of direct empirical research in date fruit systems. The review identifies the necessity of processing-marketing interventions, and suggests future research opportunities based on the date industry of Pakistan.

Keywords: Date palm, Post-harvest losses, Drying technologies, Solar drying, Hot-air drying, Packaging innovations, Vacuum packaging, Modified atmosphere packaging, Contract farming, Pre-harvest marketing.

1. INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is a Pakistani crop of great economic, nutritive and cultural value. The country is a large producer of dates in the world and has large manufacturing hubs in Sindh (Khairpur, Sukkur), Balochistan (Panjgur, Turbat) and southern Khyber Pakhtunkhwa (Dera Ismail Khan). Dates help to boost rural incomes and employment as well as agri-food exports, especially in areas where few other cash crops can be cultivated.[1] In the last ten years, there has been growth in demand of dates across the world as a natural sweetener, function food ingredient, and preservative fruit products. Pakistan has responded with an increase in area of orchards, as well as enhancement of varieties especially Dhakki cultivar. But the post-harvest management and marketing efficiency have not increased by the same

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percentage as the gains of production. Consequently, the post-harvest losses still compromise farmer earnings, resource productivity and export competitiveness.[2] Pakistan empirical studies indicate that there are consistent post-harvest losses in date fruit supply chains especially in smallholder-driven systems. The losses happen at various levels, such as pre-harvest drop of fruits, harvesting, drying, storage, and packaging, transportation, and marketing of fruits. The most common causes that have been cited include mechanical damage, lack of moisture control, insect infestation, and microbial spoilage. Significantly, a great number of wasted fruit is nutritionally viable, but does not meet fresh-market quality thresholds.[3, 4]

The process of drying and packaging date fruits is thus an area of scientific research on date fruit processing research in order to reduce losses. Controlled drying techniques such as solar dryers, greenhouse dryers, and hot-air drying have been demonstrated to enhance uniformity of moisture, reduce drying time and minimize quality loss as opposed to the open-sun drying. Vacuum packaging and modified atmosphere packaging (MAP) represent another innovation in packaging, which increase shelf life and conservation of sensory quality. Simultaneously, the expansion of value-added date products (paste, syrup, powder, and ingredients) is a potential avenue of using low-grade fruit or one that would otherwise be thrown away.[5-7] However, processing innovations cannot work if markets are not coordinated. Farmers in Pakistan are prone to uncertainty about prices, customers, and time of harvesting, thereby resulting in late harvesting, poor storage, and inefficient choice of grading. Pre-harvest marketing systems, including forward contracts, contract farming and new digital auction systems, can help alleviate these issues, ensuring that timing, quality requirements, logistics, and demand downstream are met before harvest.[8, 9] Although the success mode of contract-based marketing has been proven to be effective with vegetables and other horticultural products in Pakistan and similar economies, there are limited empirical studies on the date fruit supply chain. The majority of the research on dates focuses on post-harvest handling and processing and the little incorporation of marketing mechanisms in loss-reduction processes. This is

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an especially important gap considering seasonal concentration of date harvests, varietal heterogeneity, and high percentage of fruit sold to non-fresh markets.[10, 11]

The current review aims to

i. Synthesize recent literature (2019–2024) on drying technologies and packaging innovations relevant to Pakistan's date sector
ii. Summarize evidence on post-harvest losses and measurement methods and
iii. Critically examine how a contract-based pre-harvest marketing system could be used to minimize losses and achieve better returns to farmers.

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2. METHODS

2.1 Data Source and Search Strategy

The review was done according to a systematic search of the literature on Google Scholar as the main database. The search was carried out in the period between January and March 2025 with the following key word combinations:

- Losses at date palm after harvest.
- Drying of date fruit technology.
- Date fruit package shelf life.
- Forward contracting agriculture.
- Post-harvest loss-contract farming.
- Digital e-auction farmers.

2.2 Inclusion and Exclusion Criteria

Inclusion Criteria

- Peer-reviewed journal articles and authoritative reports.
- Published between 2019 and 2024
- Specializes in processing date fruits or marketing farming on contractual basis.
- Quantitative information of losses, quality, shelf life or revenues.

Exclusion Criteria

- Non-English articles
- Opinion articles which lack empirical or analytical backing.
- Surveys of non-fruits crops only and without any transferable information.

2.3 Study Selection

Initially, 52 studies were identified. Following the screening of titles and the abstract, a total of 24 articles were left to be subjected to the full-text review. The final synthesis included 22 studies based on the relevance and the quality of the data.

3. RESULTS

3.1 Post-Harvest Losses in Pakistani Date Supply Chains

Pakistan experience shows that usually between 25% and more than 40% of date supply chains make losses after harvest, depending on cultivar, region, and handling.

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Investigations into the Dhakki date variety in Dera Ismail Khan document especially great losses at farm, wholesale, and retail stage, indicating a poor infrastructure and less availability to controlled dryland.[12]

The post-harvest loss is normally estimated as:[12]

$$\text{PHL}(\%) = \frac{Q_h - Q_m}{Q_h} \times 100$$

where Q_h represents harvested quantity and Q_m denotes marketable quantity.

For example, if 1,000 kg of dates are harvested and only 780 kg reach the market in acceptable condition, the calculated loss equals 22%.

In research, harvesting and drying processes have the highest proportion of losses especially when it is sun dried without screening against dust, insects, and changes in moisture.[4]

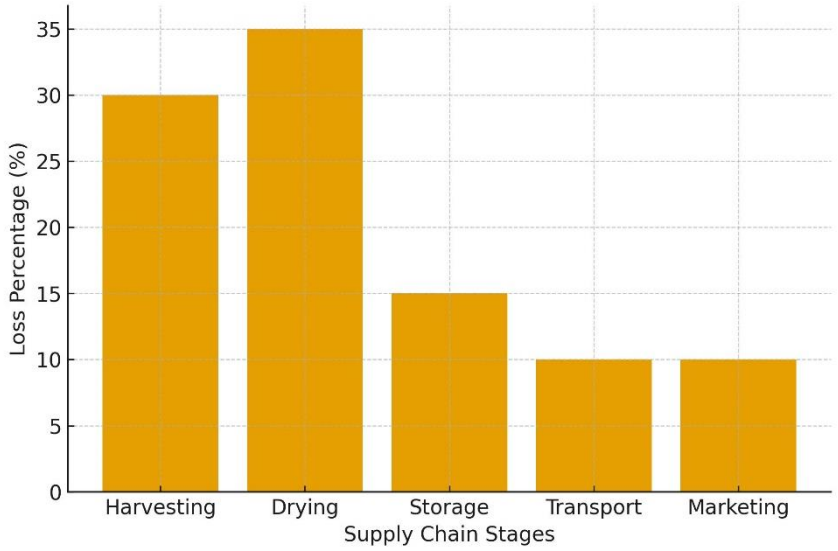

Figure 3.1.1 Post Harvest Losses across Different Stages

3.2 Drying Technologies

The date industry in Pakistan still relies on traditional open-sun drying as a result of the minimal capital needs. Nevertheless, research always indicates a slow moisture elimination, non-uniform drying and high microbial risks following such a method.

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Achieved controlled drying technologies include solar cabinet dryers, greenhouse dryers and hot-air dryers that prove to be better in terms of drying speed and moisture control.[13]

Drying efficiency is usually modeled on the basis of moisture ratio (MR) which is expressed as:[14]

$$MR = \frac{M_t - M_e}{M_0 - aM_e}$$

Where is M_t moisture content at time t, M_0 is initial moisture content, and M_e is equilibrium moisture content.

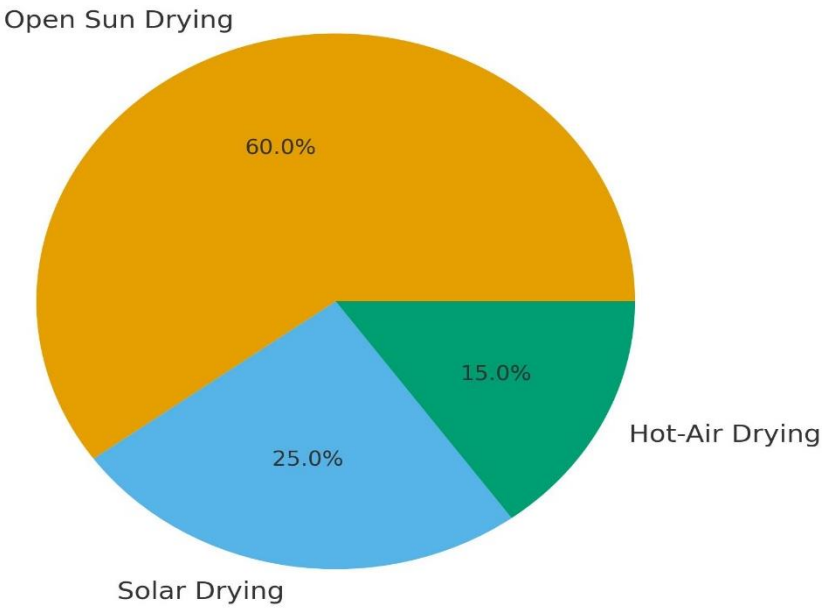

Figure 3.2.2 Distribution of Drying Methods Reported in Studies

Trial drying experiments in conditions that are pertinent to South Asian conditions have consistently indicated a faster decrease in MR and reduced equilibrium moisture in a controlled drying system relative to open sun drying. These are the improvements that contribute to the increased shelf stability because of the decreased vulnerability to microbial growth. Nevertheless, although the reduction in moisture content is generally acknowledged as a condition to reduce spoilage, few studies directly

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measure the rates of storage spoilage after application of various drying methods, thus the need to have longitudinal trials of storing food in Pakistan.[15, 16]

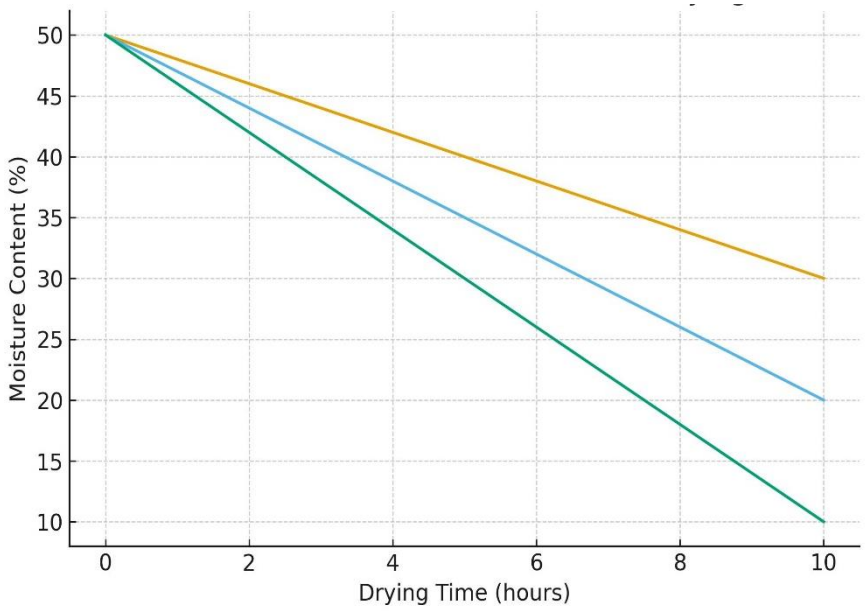

Figure 3.2.3 Moisture reduction over time under different drying technologies.

3.3 Packaging Innovations

It has been shown that packaging interventions possess an obvious impact on the prolongation of storage dates on dried dates. In Pakistan, or traditional method of packaging, it is normally possible to store a product of about 3-4 months under ambient conditions. In comparison, vacuum and modified atmosphere packaging (MAP) and especially when combined with low-temperature storage have a significant shelf life extension.[17-19]

The performance of shelf-life can be presented in terms of the shelf-life extension ratio (SER):

$$SER = \frac{SL_i - SL_t}{SL_t}$$

where is SL_t improved shelf life and is SL_i traditional shelf life.

For example, increasing storage duration from 4 to 10 months results in:

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$$SER = \frac{10 - 4}{4} = 1.5$$

indicating a 150% improvement. Although the majority of evidence is obtained in controlled experiments, not in commercial Pakistani supply chains, the results are in line with the positive changes observed in other similar date-producing areas.

3.4 Contract-Based Pre-Harvest Marketing

There is little direct empirical evidence of a relationship between pre-harvest contracting and post-harvest losses within Pakistani date supplying chains. Nevertheless, the research carried out in the vegetable and horticultural industries in Pakistan shows that forward contracts and contract farming schemes usually minimize losses by 10-25%. Such declines are credited to the timing of better harvest, quality incentives as well as the way of logistics coordination.[20-22]

Income effects under contract arrangements are typically expressed as:

$$\Delta I = (PcQc) - (PsQs)$$

where Pc and Qc denote contracted price and quantity, and Ps and Qs represent spot-market outcomes. Income increment of horticultural crops in the area has been reported by between 8-30% implying that the date industry has high applicability in Pakistan.

4. DISCUSSION

The literature review shows that drying and packaging technological advances can significantly minimize physical and quality losses of date fruits. But even processing can never be a complete solution to post-harvest loss in Pakistan in case there are still inefficiencies in the marketing. Other horticultural industries indicate that pre-harvest contracting improves the returns of post-harvest technologies because it matches production choices with market demands.[1, 20-22]

Pakistani date supply chains could alleviate uncertainty by digitally or contractually selling pre-harvest marketing platform products through controlled drying facilities, promote early fruit grading, and for low-grade fruit, direct towards processing markets instead of waste. The limited number of empirical trials in dates is an

Online ISSN 3007-3197
Print ISSN 3007-3189
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indication of a research gap and not potential.[2, 8, 9]

6. FUTURE PERSPECTIVES

One recommendation of future research is pilots and randomized testing of digital pre-harvest bidding, forward contracts, and grade-based pricing systems in the date supply chains of Pakistan. The integration of these marketing mechanisms with current drying and packaging technologies presents a positive avenue to minimize wastage, value addition and to intensify smallholder involvement in high-value markets.

5. CONCLUSION

The supply chains of the date fruit in Pakistan continue to experience significant post-harvest losses even after the introduction of the modern technologies in the processing. It is evident that modern methods of drying and packaging enhance moisture, shelf life and quality preservation. Experience in other related horticultural industries also shows that the mechanism of marketing of contracts would further decrease the loss and increase the farmer earnings. Nevertheless, there is a lack of empirical evidence that directly connects such mechanisms to date fruit systems in Pakistan, which is why it is worth further integrated processing-marketing research.

6. REFERENCES

1. Solangi N, Abul-Soad AA, Jatoi MA, Mirani AA, Markhand GS. Date Palm Cultivation, Consumption and Export: Current Status and Future Challenges-A Review. Proceedings of the Pakistan Academy of Sciences: B Life and Environmental Sciences. 2024;61(4):333-50.
2. El-Beltagi HS, Shah ST, Mohamed HI, Alam N, Sajid M, Khan A, et al. Physiological response, phytochemicals, antioxidant, and enzymatic activity of date palm (Phoenix dactylifera L.) cultivated under different storage time, harvesting stages, and temperatures. Saudi Journal of Biological Sciences. 2023;30(11):103818.
3. Oladzad S, Fallah N, Mahboubi A, Afsham N, Taherzadeh MJ. Date fruit processing waste and approaches to its valorization: A review. Bioresource

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Technology. 2021;340:125625.

4. El-Habbab MS, Al-Mulhim F, Al-Eid S, Abo El-Saad M, Aljassas F, Sallam A, et al. Assessment of post-harvest loss and waste for date palms in the Kingdom of Saudi Arabia. International Journal of Environmental and Agriculture Research. 2017;3(6):1-11.
5. Sarhadi H, Sadeghizadeh-Yazdi J. The effect of modified atmosphere packaging on physicochemical, microbial, and sensorial properties of Iranian mazafati date. Journal of food quality and hazards control. 2019.
6. Munoz-Bas C, Munoz-Tebar N, Candela-Salvador L, Sayas-Barbera E, Viuda-Martos M, Perez-Alvarez JA, et al. Development of value-added products suitable for food applications from fresh date fruit (Confitera cv.) and its co-products. Food and Bioprocess Technology. 2024;17(5):1265-77.
7. Elwakeel AE, Tantawy AA, Alsebiey MM, Elliby AK. The date fruit drying systems: acritical over review. Al-Azhar Journal of Agricultural Engineering. 2022;3(1):26-36.
8. Akhtar S, Abbas A, Iqbal MA, Rizwan M, Samie A, Faisal M, et al. What determines the uptake of multiple tools to mitigate agricultural risks among hybrid maize growers in Pakistan? Findings from field-level data. Agriculture. 2021;11(7):578.
9. Federgruen A, Lall U, Şimşek AS. Supply chain analysis of contract farming. Manufacturing & Service Operations Management. 2019;21(2):361-78.
10. Benmehaia MA. Farmers' income risks and marketing channel choices: Case of date palm processing in Biskra, Algeria. New Medit: Mediterranean Journal of Economics, Agriculture and Environment= Revue Méditerranéenne d'Economie Agriculture et Environment. 2019;18(3).
11. Faiza BS. Analysis of Date's Market Functioning (Phoenix Dactylifera L), in Ouargla, South-Est of Algeria: Challenges and Constraints. 2022.
12. Suhail M, Durrani Y, Hashmi MS, Muhammad A, Ali SA, Uzair M, et al. Postharvest losses of dhakki dates during supply chain in Pakistan. Fresenius

Online ISSN 3007-3197
Print ISSN 3007-3189
http://amresearchreview.com/index.php/Journal/about

Environmental Bulletin. 2020;29(1):299-309.

13. Sultana S, Hussain S, Farooq M, Ehsan M. Solar Dryer for Large/Medium Scale Ripening and Drying of Dates; A Case Study of Dates Growing Area of Pakistan: A Case Study of Dates Growing Area of Pakistan. Biological Sciences - PJSIR. 2021;64(1):30-7.
14. ABODUNRIN OD. Mathematical Modelling of Thin Layer Drying Kinetics of Pre-Treated Date Fruits (Phonenix dactylifera L.): Federal University of Technology, Akure.; 2023.
15. Desai N, Modi V, Patel J. FARMERS'PROSPERITY THROUGH SOLAR DRYING OF DATES.
16. Ujong AE, Emelike NJT, Ofiks A, Ohanehi HA, Olumide BA. Effect of drying methods and variety on the chemical composition, functional, and microbial properties of date flour. JSFA Reports. 2024;4(12):398-405.
17. Mortazavi S, Arzani K, Barzegar M, editors. Effect of vacuum and modified atmosphere packaging on the postharvest quality and shelf life of date fruits in khalal stage. III International Date Palm Conference 736; 2006.
18. Al-Eid SM, Barber AR, Rettke M, Leo A, Alsenaien WA, Sallam AA. Utilisation of modified atmosphere packaging to extend the shelf life of Khalas fresh dates. International journal of food science and technology. 2012;47(7):1518-25.
19. Ahmed AR, Aleid SM, Mohammed M. Impact of modified atmosphere packaging conditions on quality of dates: Experimental study and predictive analysis using artificial neural networks. Foods. 2023;12(20):3811.
20. Ghafoor A. Building horticulture value chains and reducing postharvest losses in Pakistan. 2022.
21. Khan MF, Nakano Y, Kurosaki T. Impact of contract farming on land productivity and income of maize and potato growers in Pakistan. Food Policy. 2019;85:28-39.
22. Ton G, Desiere S, Vellema W, Weituschat S, D'Haese M. The effectiveness of contract farming for raising income of smallholder farmers in low-and middle-income countries: A systematic review. Campbell Systematic Reviews.

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http://amresearchreview.com/index.php/Journal/about

2017;13(1):1-131.