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FRESH BERRY SUPPLY CHAIN DYNAMICS AND POSTHARVEST LOSSES OF JAMUN (*Syzygium cumini* L. Skeels.) IN CENTRAL AND SOUTHERN PUNJAB, PAKISTAN

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ABSTRACT

Jamun (*Syzygium cumini* (L.) Skeels) is a nutritious but highly perishable fruit whose commercialization in Pakistan is constrained by fragmented marketing arrangements and rapid postharvest deterioration. This study mapped the structure and governance of fresh jamun supply chains and documented the principal types and points of postharvest loss in Central and Southern Punjab. Data were collected through semi-structured interviews with 225 value-chain stakeholders, comprising growers, pre-harvest contractors, commission agents, wholesalers, retailers and consumers in Bahawalpur, Multan and Faisalabad (including Samundri). Three commercial plantations and selected consignments were also followed from harvest through wholesale, retail and consumer stages. Descriptive statistics and thematic content analysis identified three coexisting channels: traditional, modern and export. The traditional chain handled the largest volume and served consumers across income groups, but it was relatively long, fragmented and characterized by weak information exchange and spot-market coordination. Modern chains handled smaller volumes of better-graded fruit for supermarkets and specialized outlets, whereas export chains supplied limited quantities of high-quality fruit in smaller, branded packages. Visible losses began at harvest and continued throughout distribution. Fruit cracking and excessive softening were prominent during harvesting and packing, while bruising, softening, shrivelling and insect damage reduced quality during transport and marketing. The study shows that jamun-sector upgrading requires extension support that combines improved harvesting, field sorting, protective packaging, rapid transport and low-cost temperature management with stronger market information, grading standards and collaboration among growers and buyers. These interventions could reduce avoidable quality loss and improve returns across the chain.

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INTRODUCTION

Jamun (*Syzygium cumini* (L.) Skeels), also known as Java plum or jambolan, is an underutilized fruit tree adapted to tropical and subtropical environments. The ripe berry is generally oval, dark purple to blue-black and characterized by a sweet-acidic, mildly astringent flavour. Jamun

germplasm in Pakistan exhibits substantial phenotypic diversity, indicating opportunities for selection, orchard improvement and commercial development (Safeer ud Din et al., 2020). The edible pulp contains sugars, minerals, dietary fibre, organic acids, anthocyanins and other phenolic compounds that contribute to its nutritional and

antioxidant value (Lestario et al., 2017; Seraglio et al., 2018). The fruit can also be processed into beverages, preserves, vinegar and other value-added products (de Sousa Sabino et al., 2018). Despite these attributes, jamun remains weakly commercialized in Pakistan. Production is dominated by seedling-origin trees and scattered orchards, while harvesting, grading, packaging and marketing practices are largely informal. Fresh fruit quality declines quickly after harvest, particularly under warm ambient conditions, which limits the marketing period and increases the risk of physical and physiological deterioration. Research in Pakistan has shown that orchard conditions and postharvest treatments influence jamun quality and shelf life, confirming the importance of handling and temperature management after harvest (Aslam et al., 2020).

Agri-food value chains connect input suppliers, producers, intermediaries, processors, retailers and consumers through linked product, financial and information flows (Batt, 2009; Gagnon, 2012; Neven, 2014). Each actor performs functions that can add, preserve or destroy value. Consequently, chain performance depends not only on production but also on coordination, quality management, logistics and the distribution of information and incentives among participants (Aramyan et al., 2007; Collins, 2009; Kannegiesser et al., 2008). In developing economies, traditional channels commonly coexist with modern retail and export channels, and the governance requirements of these channels differ substantially (Ruben et al., 2007; Trienekens, 2011). Studies of Pakistan's mango industry have demonstrated that traditional, modern and export value chains can operate simultaneously, with important differences in product quality, market destination, information exchange and buyer-seller coordination (Badar et al., 2019). Similar structural diversity is likely in the jamun sector, particularly because modern retailing is expanding while traditional markets remain the principal outlet for fresh produce (Ghani, 2005; Shah et al., 2007).

However, documented evidence on the organization of jamun marketing channels, actor relationships and postharvest loss points is scarce.

This study therefore aimed to: (i) identify and characterize the main fresh jamun supply chains operating in Central and Southern Punjab; (ii) examine product, financial and information flows and the governance features of these chains; (iii) document the major visible types and stages of postharvest loss from harvest to consumption; and (iv) propose practical upgrading measures with particular relevance to agricultural extension and market-support services.

METHODOLOGY

Study design and area

A cross-sectional, qualitative-dominant value-chain assessment was conducted in the principal jamun production and marketing clusters of Bahawalpur, Multan and Faisalabad, including the Samundri production area. These locations were selected because they combine commercial jamun production with active wholesale and retail markets in Central and Southern Punjab. The study integrated stakeholder interviews, supply-chain mapping, direct observation of handling operations and descriptive analysis of respondent characteristics.

Respondent selection and sample composition

Because no complete sampling frame was available for the dispersed jamun trade, respondents were identified through snowball sampling (Saunders et al., 2009). Initial contacts in retail and wholesale markets helped identify commission agents, contractors and growers; respondents then referred the research team to other actors involved in the chain. The final sample comprised 225 participants: 40 growers, 35 pre-harvest contractors, 30 commission agents, 30 wholesalers, 30 retailers and 60 consumers (Table 1).

Table 1. Composition and distribution of the study sample (n = 225).

Stakeholder	Bahawalpur	Multan	Faisalabad	Total
Growers	10	10	20	40
Pre-harvest contractors	10	10	15	35
Commission agents	10	10	10	30
Wholesalers	10	10	10	30
Retailers	10	10	10	30
Consumers	20	20	20	60
Total	70	70	85	225

N= 225.

Source: authors' calculations

Interview instrument and data collection

Semi-structured interview guides were developed for each stakeholder category after reviewing relevant value-chain literature and adapting earlier survey formats used for horticultural chains in Pakistan (Badar et al., 2019). The guides covered business characteristics, sourcing and selling relationships, quality requirements, packaging, price formation, information exchange, payment flows, constraints and opportunities for upgrading. The instruments were pilot tested before field implementation, and responses were recorded on standardized interview schedules during personal interviews.

Supply-chain mapping and postharvest observations

Interview evidence was used to map the sequence of actors and to classify chains according to their dominant retail outlet and market destination. Particular attention was given to the movement of fruit, payments and market information, as well as the degree of coordination among actors. In parallel, three commercial jamun plantations, one in each study area, were monitored during harvesting, sorting and packing. Selected fruit consignments were then followed through contractor, wholesale, retail and consumer stages. Observations recorded the stage at which visible deterioration occurred and the dominant symptoms, including cracking, softening, bruising, shrivelling and insect damage. The observational component documented loss types and process points; it did not estimate losses by weight, percentage or monetary value.

Data analysis

Quantitative responses were entered in Microsoft Excel and summarized using frequencies and percentages. Qualitative responses and field observations were coded and analyzed through thematic content analysis following the general procedures of familiarization, coding, theme development and review described by Braun and Clarke (2006). Themes were compared across actor categories and locations to identify common chain structures, governance patterns, quality requirements and postharvest constraints.

RESULTS

Profile of supply-chain participants

Respondent profiles varied across actor categories (Table 2). Most growers, contractors and commission agents were 31-40 years old, whereas wholesalers and retailers were more evenly distributed across the 31-40- and 41-50-year groups. Educational attainment was highest among commission agents and consumers: 40% of commission agents and 60% of consumers were graduates. By contrast, 80% of wholesalers and retailers had primary education or no formal education. Most actors reported up to 10 years of experience. Contractors (80%), wholesalers (60%), retailers (60%) and consumers (80%) were concentrated in the 6-10-year category, while 80% of commission agents reported five years or less. Household size was commonly four to ten persons, although 20% of commission agents reported households larger than ten persons.

Table 2. Demographic profile of fresh jamun supply-chain participants (% within stakeholder group).

Variable	Category	Growers (n=40)	Contractors (n=35)	Commission agents (n=30)	Wholesalers (n=30)	Retailers (n=30)	Consumers (n=60)
Age (years)	Up to 30	20	40	40	20	20	40
	31-40	80	60	60	40	40	60
	41-50	-	-	-	40	40	-
	51-60	-	-	-	-	-	-
	Over 60	-	-	-	-	-	-
Education	Illiterate	-	-	-	40	40	-
	Primary ¹	-	-	-	40	40	-
	Secondary ²	60	40	20	20	20	20
	Higher secondary ³	20	40	40	-	-	20
	Graduate	20	20	40	-	-	60
	Postgraduate	-	-	-	-	-	-
Experience (years)	Up to 5	40	20	80	40	40	20
	6-10	60	80	20	60	60	80
	11-15	-	-	-	-	-	-
	16-20	-	-	-	-	-	-
	Over 20	-	-	-	-	-	-

Family size	Up to 4	40	40	40	40	40	20
(persons)	5-7	20	20	40	20	20	-
	8-10	40	40	-	40	40	-
	Over 10	-	-	20	-	-	-

¹ Grade 5; ² Grade 10; ³ Grade 12. A dash indicates no respondents in that category.

Structure of fresh jamun supply chains

The jamun industry comprised interlinked groups of growers, pre-harvest contractors, commission agents, wholesalers, retailers, exporters and consumers. Three broad chain types operated concurrently: traditional, modern and export (Figure

1). The chains were not completely isolated. Actors occasionally sourced fruit across channels when their usual suppliers could not meet requirements, but each chain was distinguished by its dominant outlet, customer group, product specifications and level of coordination.

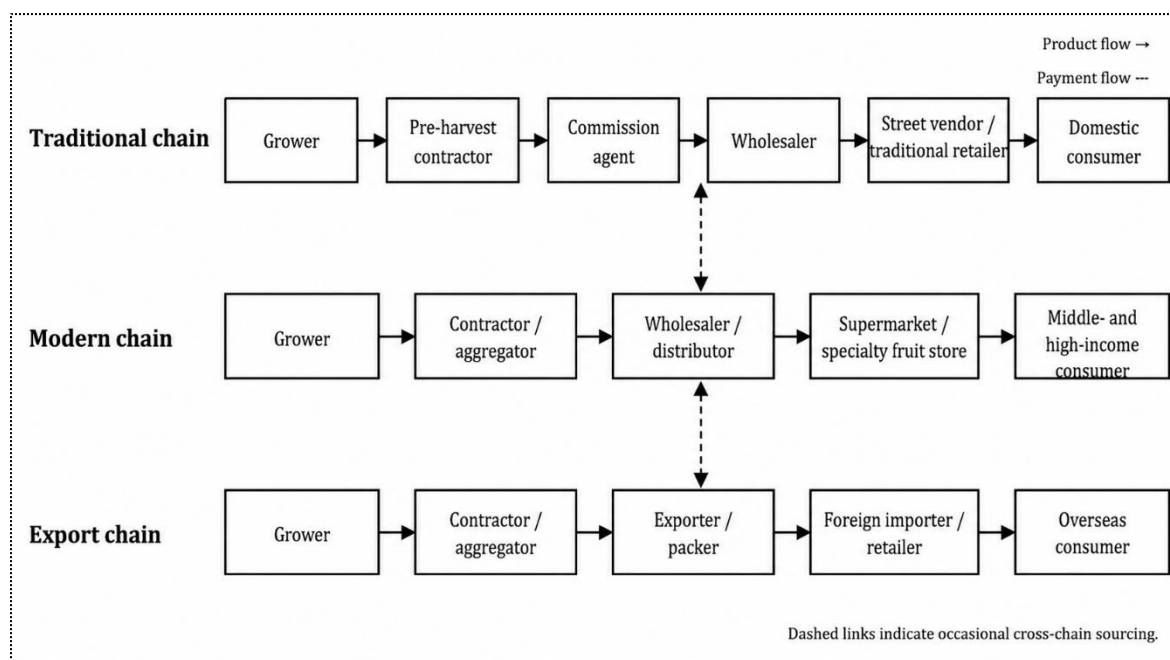


Figure 1. Structure and principal product flows of fresh jamun supply chains in Central and Southern Punjab, Pakistan.

Characteristics of traditional, modern and export chains

The traditional chain handled the largest share of fruit and supplied consumers across income groups through conventional wholesale markets, street vendors and traditional retailers. Fruit was commonly marketed in bulk wooden baskets of 20-25 kg, with basic sorting and mixed quality grades. Information exchange was limited, and transactions were largely driven by immediate market conditions. The modern chain handled a smaller volume but emphasised better sorting, medium-sized cardboard packages, and sales through supermarkets, megastores, or specialised fruit shops. The export chain handled only a very small share of production and required higher-quality fruit, good grading and smaller packages, including branded cardboard boxes or plastic baskets (Table 3).

Product, financial and information flows

In all three chains, fruit moved from growers toward consumers and payments moved in the opposite direction. The principal differences concerned the strength and timing of information exchange and the degree to which quality requirements influenced transactions. Traditional-chain actors reported limited feedback on consumer preferences, grading and handling, and price signals were largely transmitted through daily wholesale-market transactions. Modern and export channels had clearer requirements for fruit appearance, package size and presentation, which strengthened communication between buyers and upstream suppliers. Nevertheless, the small volume handled by these channels limited their influence on the overall sector.

Postharvest loss patterns along the chain

Visible quality loss began during harvesting and persisted through packing, transport, wholesale and retail. Fruit cracking and excessive softening were the main problems observed at harvest and during initial sorting and packing. During transport from farms to wholesale markets, bruising and compression were associated with further softening. At

wholesale and retail stages, continued moisture loss and ripening produced shrivelling, loss of firmness and reduced visual appeal. Insect-damaged fruit was also encountered and was downgraded or rejected. Because the study did not use weight-based sampling, these observations indicate the dominant types and points of loss rather than the percentage magnitude of loss at each stage.

Table 3. Main characteristics of fresh jamun supply chains in Punjab.

Characteristic	Traditional chain	Modern chain	Export chain
Typical package size	Bulk, 20-25 kg	Small to medium, 8-9 kg	Small, 3-4 kg
Packaging material	Wooden basket	Cardboard box	Cardboard box or plastic basket, often branded
Retail outlet / market	Traditional retailer or street vendor	Supermarket, megastore or specialty fruit store	Foreign importer and retailer
Relative product volume	Major	Minor	Very small
Typical quality	Mixed	Good	High
Grading	Basic	Good	Good
Information flow	Weak	Strong	Strong
Consumer segment	Domestic; all income groups	Domestic; mainly middle- and high-income groups	Foreign consumers
Indicative price per kg	Low to medium (PKR 200-250)	High (PKR 350-400)	High; variable by grade and destination

Note: Prices are respondent-reported indicative values for the study period and should be interpreted in relation to grade, outlet and destination.

DISCUSSION

Coexistence and governance of jamun value chains

The coexistence of traditional, modern and export chains is consistent with broader patterns reported for horticultural markets in developing countries (Ruben et al., 2007; Trienekens, 2011) and with evidence from Pakistan's mango sector (Badar et al., 2019). Traditional channels remain dominant because they aggregate dispersed production, accept mixed grades and reach consumers through widely accessible outlets. These features provide market access, but the long sequence of intermediaries and weak information exchange reduce traceability and make coordinated quality improvement difficult. Similar transformations have been observed where traditional food markets coexist with emerging modern retail formats (Gómez and Ricketts, 2013).

Modern and export chains place greater emphasis on consistent quality, grading, package size and presentation. These requirements can create incentives for better handling and closer coordination with suppliers. However, the findings show that these channels currently handle only a small proportion of jamun. Their expansion therefore

depends on a reliable supply of marketable fruit, improved postharvest management and stronger linkages between growers, aggregators and quality-oriented buyers. The development of modern retail in Pakistan may gradually increase demand for such coordination (Ghani, 2005; Shah et al., 2007), but the benefits will not reach growers automatically unless quality standards and price incentives are clearly communicated upstream.

Postharvest deterioration and its causes

The concentration of losses around cracking, softening, bruising and shrivelling reflects the high perishability of ripe jamun. Under ambient conditions, quality changes rapidly, and orchard location and postharvest treatment can markedly influence shelf life (Aslam et al., 2020). The study's observations also agree with general postharvest evidence that rough handling, heavy packages, repeated transfer, transport vibration, high temperature and delayed marketing accelerate physical injury and water loss in fresh fruit (Kader, 2002; Kitinoja and Kader, 2015). Insect damage further reduces marketable quality and can increase sorting losses when damaged fruit is mixed with

sound fruit. The traditional use of 20-25 kg wooden baskets is particularly important from a loss-prevention perspective. Large bulk packages increase the pressure on fruit in lower layers and make careful handling more difficult. By comparison, the smaller packages used in modern and export channels are better suited to a soft, delicate berry, although package design, ventilation and stacking practices still require evaluation under local conditions. The results therefore indicate that postharvest upgrading should focus on the entire handling sequence rather than on a single technology.

Implications for agricultural extension and chain upgrading

Agricultural extension can play a central role in converting the study findings into practical change. First, growers and harvesting crews require training on harvest maturity, gentle detachment, avoidance of fruit dropping, immediate field shade and removal of cracked or insect-damaged fruit. Second, demonstrations should compare existing bulk baskets with smaller, smooth-surfaced and ventilated crates or cartons to show the effects of package size and handling on bruising and softening. Third, extension messages should promote rapid movement to market, transport during cooler hours where feasible, clean loading surfaces and protection from direct sun.

Technical advice should be combined with market-oriented extension. Common grade descriptions, simple quality records, daily price and demand information, and buyer-grower meetings would improve communication and reduce uncertainty. Producer groups could aggregate better-quality fruit, purchase improved packages collectively and negotiate directly with modern retailers or exporters. Pilot testing of low-cost cooling, evaporative storage and short cold-chain segments is also warranted. These interventions align with the broader principle that value-chain performance depends on coordinated improvements in product quality, information, relationships and logistics rather than isolated farm-level recommendations (Aramyan et al., 2007; Neven, 2014).

Study limitations

The use of snowball sampling was appropriate for identifying a dispersed and informal network, but it does not provide a statistically representative estimate of all jamun actors in Punjab. The study documented visible loss symptoms and chain practices but did not quantify loss by weight, percentage, nutritional quality or monetary value.

Price data were respondent-reported and may vary by season, grade and market. Future studies should therefore use repeated seasonal measurements, standardized load tracking, temperature and humidity monitoring, and economic loss assessment. Gender-disaggregated participation and consumer preference analysis would also broaden understanding of the sector.

CONCLUSION

Fresh jamun marketing in Central and Southern Punjab is organized through three coexisting supply chains. Traditional chains dominate volume and market reach but are relatively long, fragmented and weak in information exchange. Modern and export chains handle smaller quantities and apply stronger quality, grading and packaging requirements. Across all channels, visible deterioration begins at harvest and continues through distribution, with cracking, softening, bruising, shrivelling and insect damage representing the principal loss patterns. Reducing these losses requires coordinated technical and institutional upgrading. Extension programs should promote gentle harvesting, immediate shade and sorting, smaller protective packages, faster transport, basic temperature management and chain-wide hygiene. At the same time, market information, grade standards, record keeping, producer organization and structured buyer-grower linkages should be strengthened. Quantitative loss measurement and economic evaluation are the next research priorities for identifying the most cost-effective interventions and supporting the commercial development of jamun in Pakistan.

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Appendix



Figure 1a. Various steps of fresh jamun fruit harvesting and packings: fruit harvesting (A-C), fruit sorting (D-H) and fruit packings (I).



Figure 1b: Various postharvest losses observed during fresh jamun fruit supply chain: losses due to insect infestations (A-B) and fruit cracking (C-D).

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