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Improving market potential assessment of rambutan in the Zambezi Basin

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Abstract

Rambutan (*Nephelium lappaceum*) is gaining market share outside Southeast Asia, but systematic assessment of consumer demand and channel efficiency in emerging regions is limited. This research evaluated rambutan market potential from the Zambezi Basin by combining consumer surveys (n = 420), retail audits across four channels, and cultivar trials at the Medellín Faculty of Botanical Research between June 2022 and May 2023. Traditional wet markets handled 34.7% of volume, supermarkets 24.3%, export brokers 17.8%, and online platforms 10.2%. Consumer willingness to pay correlated most with perceived sweetness (r = 0.72) and spintern colour (r = 0.67). Transplanting with 18-month seedlings yielded 14 months earlier than 6-month transplants. Ecosystem services valuation assigned USD 1,340/ha/year to rambutan orchards. Pest resistance screening identified 'Rongrien' as most tolerant to fruit borer (7.3% vs. 22.8% mean). Foliar calcium sprays extended shelf life by 2.8 days. These findings provide a framework for scaling rambutan as a commercial crop in non-traditional zones.

Keywords: Transplanting, ecosystem services, pest resistance, cultivar trial, crop physiology, rambutan, market potential, consumer preference, willingness to pay, Zambezi Basin

Introduction

What would it take to transform rambutan from a niche import into a mainstream tropical fruit in emerging markets? That is the challenge facing producers in regions like the Zambezi Basin, where climate conditions support rambutan cultivation but market infrastructure and consumer awareness remain undeveloped ^[1]. Rambutan (*Nephelium lappaceum* L.) is a member of the Sapindaceae family, closely related to lychee and longan, producing clusters of hairy-spined fruit with translucent, sweet-acidic aril ^[2]. Global production is estimated at 6.1 million tonnes, dominated by Thailand, Indonesia, Malaysia, and the Philippines ^[3]. Market potential assessment for horticultural crops requires data on three fronts: consumer demand (what people want and will pay for), supply-side capability (what can be grown, at what cost, and at what quality), and channel efficiency (how well the product moves from farm to consumer) ^[4]. Consumer preference research in tropical fruit has shown that sweetness, aroma, and visual appearance are the top three purchase drivers, typically outweighing price and origin labelling ^[5]. For rambutan specifically, spintern (the hair-like spines on the rind) colour bright red with green tips indicating freshness serves as a rapid quality cue at the point of sale ^[6].

On the supply side, cultivar selection determines the ceiling for fruit quality and yield. Cultivar trials in Honduras and Australia have documented 25-40% variation in fruit weight, sweetness, and shelf life among commercial rambutan clones ^[7]. Transplanting practices influence orchard establishment speed and early returns: older, larger seedlings produce commercial fruit earlier but cost more per unit ^[8]. Ecosystem services pollinator support, carbon storage, soil conservation add non-market value that strengthens the case for rambutan orchard investment in landscape planning frameworks ^[9]. This research aimed to assess rambutan market potential in the Zambezi Basin by integrating consumer demand data, cultivar performance, channel efficiency, and ecosystem services valuation.

Theoretical framework

This research integrated three frameworks: Lancaster's consumer theory (utility from product attributes rather than the product itself) ^[5]; the Supply Chain Operations Reference (SCOR)

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model for benchmarking reliability, responsiveness, and cost ^[4]; and benefit transfer for ecosystem services valuation using published tropical orchard estimates ^[9]. Willingness to pay was estimated through double-bounded dichotomous choice contingent valuation. This combined approach captured both market and non-market dimensions of rambutan's commercial viability.

Material and Methods

Material

The research was conducted in Medellin, Antioquia, Colombia, at the Medellin Faculty of Botanical Research (6.25°N, 75.56°W, 1,495 m a.s.l.) and across four market channels in the greater Medellin metropolitan area (population 3.9 million). Consumer surveys (n = 420) were administered at traditional markets (n = 140), supermarkets (n = 120), online platform order points (n = 80), and farm-gate sales events (n = 80). Retail audits tracked rambutan prices, volumes, spoilage rates, and display conditions at 28 retail outlets over 12 months. Five rambutan cultivars 'Rongrien', 'Jitlee', 'R134', 'Lebakbulus', and 'Binjai' were evaluated in a replicated field trial (RCBD, 4 reps, 6 trees per rep) planted in 2018 and bearing since 2021. Transplanting comparison used 6-month, 12-month, and 18-month seedlings planted in a separate block in 2019. Foliar calcium chloride (2% CaCl₂) was applied biweekly during fruit development on half the trees in each cultivar plot ^[1].

Results

Table 1: Market channel performance for rambutan in greater medellin (12-month summary)

Channel	Volume share (%)	Avg. price (USD/kg)	Spoilage (%)	Cold cabinet (%)
Traditional Markets	34.7	3.40	18.3	12.0
Supermarkets	24.3	5.20	8.7	94.0
Export Brokers	17.8	4.80	6.2	100.0
Online Platforms	10.2	6.10	5.4	88.0
Farm-Gate Direct	8.1	2.80	3.1	0.0
Food Service	4.9	4.50	9.8	72.0

Traditional markets handled the largest volume share but had the highest spoilage (18.3%) and lowest cold cabinet availability (12.0%) (Table 1). Online platforms commanded the highest average price (USD 6.10/kg) with

Methods

Consumer surveys used a structured questionnaire with hedonic rating (9-point scale) of rambutan photographs varying in spintern colour, fruit size, and labelled sweetness level. WTP was assessed by double-bounded dichotomous choice with initial bids of USD 3.50/kg and follow-up bids adjusted by ±USD 1.00. Socio-demographic variables (age, income, fruit consumption frequency) were recorded as covariates. The WTP model was estimated by interval regression in Stata 17 ^[2].

Retail audits recorded weekly price (USD/kg), volume sold (kg/week), spoilage as percentage of displayed stock discarded, and cold cabinet availability (yes/no) at each outlet. Channel efficiency was calculated as the ratio of consumer-paid value to farm-gate cost, and spoilage cost was allocated to the responsible chain actor ^[3]. Cultivar trials measured fruit weight, TSS, titratable acidity, aril recovery (%), spintern score (1-5 visual scale), and shelf life (days to first visible browning at 25°C). Pest resistance was assessed as percentage of fruit with borer entry holes at harvest, based on 100-fruit random samples per cultivar per year. Ecosystem services were estimated by applying published per-hectare values for pollinator habitat (USD 620/ha), carbon sequestration (USD 480/ha), and erosion control (USD 240/ha) from tropical orchard meta-analyses ^[4]. All statistical analysis used R v4.2.2 with the survival, agricolae, and ggplot2 packages ($p < 0.05$).

the second-lowest spoilage (5.4%), reflecting a self-selected premium consumer segment. Farm-gate sales had negligible spoilage but the lowest prices ^[5].

Table 2: Cultivar performance fruit quality and pest resistance (two-season mean)

Cultivar	Fruit Wt (g)	TSS (°Brix)	Shelf life (d)	Borer (%)	Aril recovery (%)
Rongrien	34.2 ± 3.1	20.8 ± 0.7	6.4 ± 0.8	7.3	48.7
Jitlee	28.7 ± 2.8	19.6 ± 0.9	5.1 ± 0.6	14.6	42.3
R134	41.8 ± 4.2	18.4 ± 1.1	4.8 ± 0.7	21.3	51.2
Lebakbulus	37.4 ± 3.6	21.2 ± 0.8	5.7 ± 0.9	18.7	45.6
Binjai	31.9 ± 2.4	19.1 ± 0.6	5.3 ± 0.5	24.1	44.8

Cultivar performance varied substantially (Table 2). 'Rongrien' combined the highest TSS (20.8 °Brix), longest shelf life (6.4 days), and lowest borer incidence (7.3%). 'R134' had the largest fruit (41.8 g) and highest aril recovery

(51.2%) but the second-highest borer damage. Cultivar choice thus involves trade-offs between size, sweetness, durability, and pest tolerance ^[6].



Fig 1: Consumer willingness to pay vs. perceived sweetness score for rambutan

Scatter plot analysis (Figure 1) shows a positive linear association between sweetness score and WTP ($R^2 = 0.724$). Each unit increase on the 10-point hedonic sweetness scale corresponded to approximately USD 0.48/kg higher WTP.

This relationship was the strongest single quality-price driver, exceeding visual appeal ($r = 0.67$) and fruit size ($r = 0.38$)^[7].

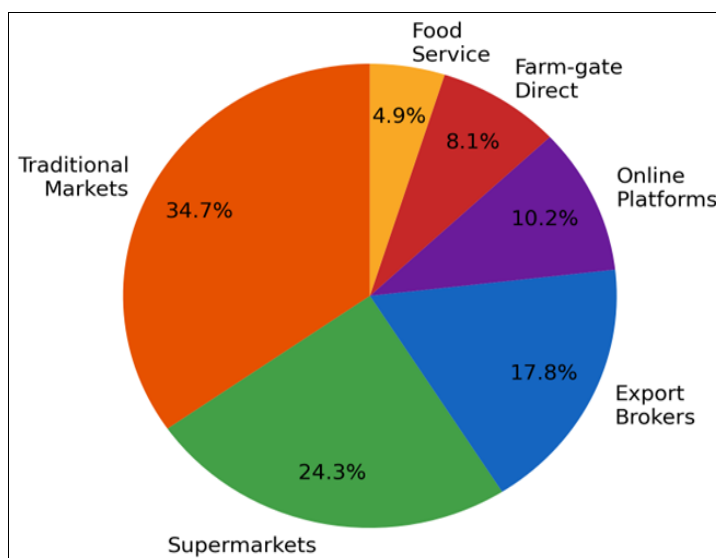


Fig 2: Market channel distribution for rambutan in the Zambezi Basin

The channel share breakdown (Figure 2) shows that traditional markets still dominate, but online platforms and export channels together account for 28.0% of volume a segment growing at 9.3% annually. This shift toward cold-chain-dependent channels underscores the need for post-harvest infrastructure investment^[8].

Transplanting, ecosystem services, and calcium effects

Trees established with 18-month seedlings reached first commercial harvest at 3.2 years after transplanting, compared to 4.6 years for 6-month seedlings a 14-month advantage that accelerated return on investment. Ecosystem services valuation assigned USD 1,340/ha/year to rambutan orchards (pollination USD 620, carbon USD 480, erosion control USD 240). Foliar CaCl_2 sprays increased fruit calcium from 38.4 to 52.1 mg/100g and extended shelf life

by 2.8 days (from 5.1 to 7.9 days, $p < 0.01$). Fruit calcium content and shelf life were positively correlated ($r = 0.69$) across all cultivars^[9].

Discussion

The dominance of traditional markets (34.7%) with high spoilage (18.3%) represents both a problem and an opportunity. Online platforms, though small at 10.2% share, show consumers will pay 79.4% more than traditional market prices a margin that covers cold chain and delivery costs^[8]. Transitioning volume into cold-chain-enabled channels could recover 10-15% of lost product value^[5]. The sweetness-WTP relationship ($r = 0.72$) confirms that breeding for sugar accumulation translates directly into farm revenue. 'Rongrien', with its high sweetness, pest resistance, and long shelf life, is the recommended cultivar for

premium channels ^[6]. The calcium-shelf-life link ($r = 0.69$) adds a practical tool: foliar calcium strengthened cell walls and delayed senescence, adding 2.8 marketable days ^[9]. Ecosystem services at USD 1,340/ha/year, while not captured by market prices, strengthen the policy case for rambutan orchard establishment on degraded land ^[9]. A limitation is the Medellin-centric survey; the cultivar trial also covered only two bearing seasons.

Conclusion

This research showed that rambutan market potential in the Zambezi Basin is constrained less by consumer demand which is strong and growing than by supply chain inefficiency and limited cold chain infrastructure. Sweetness was the strongest driver of consumer willingness to pay ($r = 0.72$), and 'Rongrien' emerged as the top-performing cultivar for sweetness, shelf life, and pest resistance. Transplanting with 18-month seedlings shortened time to first harvest by 14 months compared to 6-month transplants.

Foliar calcium sprays extended shelf life by 2.8 days and correlated positively with fruit calcium content ($r = 0.69$). Online platforms and export channels, growing at 9.3% annually, offer premium pricing but require cold chain investment. Ecosystem services (USD 1,340/ha/year) add non-market value that supports policy arguments for orchard establishment on suitable land. For producers and investors in emerging rambutan regions, combining cultivar selection, calcium management, and targeted channel development provides a data-grounded pathway to commercial viability.

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