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Yohannes Tadesse

Department of Floriculture
and Landscaping, Dire Dawa
Advanced School of
Environmental Agriculture,
Dire Dawa, Dire Dawa,
Ethiopia

Bethlehem Wolde

Department of Floriculture
and Landscaping, Dire Dawa
Advanced School of
Environmental Agriculture,
Dire Dawa, Dire Dawa,
Ethiopia

Corresponding Author:

Yohannes Tadesse

Department of Floriculture
and Landscaping, Dire Dawa
Advanced School of
Environmental Agriculture,
Dire Dawa, Dire Dawa,
Ethiopia

Analyzing consumer preference surveys of broccoli in the Kimberley plateau

Yohannes Tadesse and Bethlehem Wolde

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Abstract

While broccoli ranks among the world's top-selling vegetables in temperate markets, its consumption in semi-arid regions such as the Kimberley Plateau of Western Australia remains surprisingly low. This research surveyed consumer preferences for broccoli among 612 respondents across four Kimberley townships during 2022-2023, pairing the survey with antioxidant profiling, mulching trials, and a machine-learning model that predicted purchase probability from demographic and quality variables. Freshness dominated consumer priorities (34.7 percent of preference weight), followed by price (24.1 percent), head size and shape (18.3 percent), colour intensity (14.6 percent), and geographic origin (8.3 percent). Total antioxidant capacity correlated positively with willingness-to-pay a premium ($R^2 = 0.68$). Mulching with sugarcane bagasse increased marketable yield by 23 percent and raised carbohydrate content by 11 percent compared with bare-soil controls. A random-forest classifier trained on survey responses predicted purchase decisions with 84.7 percent accuracy, identifying household income and antioxidant awareness as the two most important features. Value chain analysis showed that retailers captured 38 percent of total margin. These findings map the preference landscape for Kimberley broccoli and point toward targeted marketing strategies built around freshness assurance and nutritional messaging.

Keywords: Antioxidants, mulching, value chain, carbohydrate, machine learning, broccoli, consumer preference, Kimberley Plateau, freshness, random forest

Introduction

Broccoli is a nutritional powerhouse in cool-climate agriculture, but in the hot, dry expanses of the Kimberley Plateau it is treated more as a curiosity than a staple ^[1]. The contrast is striking: per capita consumption in Melbourne exceeds 4 kg per year, while Kimberley households average less than 0.8 kg, a gap that cannot be explained by income alone because many Kimberley communities have disposable incomes comparable to metropolitan averages ^[2].

Consumer preference research helps explain such gaps. When shoppers evaluate a vegetable, they weigh a bundle of attributes—freshness, price, appearance, taste reputation, origin—and each attribute carries a different weight depending on cultural context and market experience ^[3]. In regions where broccoli is a recent introduction, consumers may lack the reference points needed to judge quality, making freshness cues such as colour brightness and floret tightness disproportionately important.

Antioxidant content is an invisible quality attribute that could become visible through labelling. Sulforaphane, glucosinolates, and flavonoids in broccoli have been linked to reduced cancer risk and cardiovascular protection in epidemiological and clinical trials ^[4]. If consumers are made aware of these benefits, their willingness to pay may shift upward, creating a premium segment that justifies the higher logistics costs of supplying fresh broccoli to remote markets.

Agronomic interventions affect both yield and quality. Mulching conserves soil moisture, moderates root-zone temperature, and can increase carbohydrate accumulation in Brassica heads under heat stress ^[5]. Machine learning, in turn, offers a data-driven approach to predicting consumer behaviour from survey responses, potentially outperforming traditional logistic regression when variable interactions are complex and non-linear ^[6].

This research pursued four aims: to quantify the relative importance of broccoli quality attributes among Kimberley consumers; to test whether antioxidant content predicts

willingness-to-pay; to evaluate sugarcane-bagasse mulching for yield and nutritional improvement; and to build a machine-learning model that predicts purchase probability from demographic and quality-perception variables. The fieldwork was coordinated from the Dire Dawa Advanced School of Environmental Agriculture, Ethiopia, using survey data and trial results from Kimberley collaborators [7].

Material and Methods

Reagents and Chemicals

Total antioxidant capacity was measured by the ferric-reducing antioxidant power (FRAP) assay using 2,4,6-tri(2-pyridyl)-s-triazine (TPTZ, Sigma-Aldrich), ferric chloride hexahydrate, and sodium acetate buffer at pH 3.6. Ascorbic acid equivalents (AAE) served as the reference standard. Carbohydrate was determined by the phenol-sulphuric acid method with glucose as the calibration standard. All reagents were of analytical grade sourced from Merck (Darmstadt, Germany). Absorbance readings were taken on a Shimadzu UV-1800 spectrophotometer at 593 nm (FRAP) and 490 nm (carbohydrate) [8].

Quality Control Procedures

FRAP assay linearity was confirmed across 0-1000 μmol AAE/L with $R^2 = 0.998$. Each analytical batch included a reagent blank, a spiked recovery sample (target 90-110 percent), and a laboratory control sample of freeze-dried broccoli powder with established reference values. Survey instruments were pilot-tested for internal consistency

(Cronbach's $\alpha = 0.87$) and test-retest reliability ($r = 0.91$ over a two-week interval) before full deployment [9].

Material

The commercial hybrid 'Marathon' was grown at two Kimberley trial sites (Kununurra and Broome) in raised beds with drip irrigation, using four treatments: bare soil (control), sugarcane bagasse mulch at 5 t/ha, bagasse at 10 t/ha, and black polyethylene mulch. Each treatment was replicated five times in a randomised complete block design. Consumer surveys were administered face-to-face in English at supermarkets, outdoor markets, and community centres in Kununurra, Broome, Derby, and Halls Creek from May 2022 to April 2023.

Methods

Preference weights were derived from best-worst scaling (MaxDiff) analysis using hierarchical Bayes estimation in Sawtooth Software Lighthouse Studio. Willingness-to-pay was elicited through a contingent valuation format with open-ended follow-up. The random-forest classifier was built in Python 3.11 using scikit-learn with 500 trees, a maximum depth of 10, and five-fold stratified cross-validation. Feature importance was assessed by mean decrease in Gini impurity. Value chain margins were calculated from tracked lot pricing at five nodes (farm, packer, wholesaler, retailer, consumer). All statistical comparisons used ANOVA and Tukey HSD at $p < 0.05$ in R 4.3.1 [10].

Results

Table 1: Agronomic and quality outcomes for broccoli under four mulching treatments at two Kimberley sites (pooled means, $n = 40$ per treatment)

Treatment	Yield (t/ha)	Head Wt (g)	Antioxidant (mg AAE/100g)	Carbohydrate (%)
Bare soil (control)	11.8 $\pm$ 1.4a	287 $\pm$ 34a	68.4 $\pm$ 7.2a	5.8 $\pm$ 0.6a
Bagasse 5 t/ha	13.2 $\pm$ 1.6ab	319 $\pm$ 38ab	74.1 $\pm$ 8.1ab	6.1 $\pm$ 0.7ab
Bagasse 10 t/ha	14.5 $\pm$ 1.8b	348 $\pm$ 41b	81.3 $\pm$ 9.4b	6.4 $\pm$ 0.8b
Polyethylene	13.9 $\pm$ 1.7b	332 $\pm$ 39b	77.6 $\pm$ 8.8ab	6.2 $\pm$ 0.7ab

Different letters indicate significant differences (Tukey HSD, $p < 0.05$). Bagasse at 10 t/ha gave the highest yield, antioxidant content, and carbohydrate concentration.

Table 2: Random-forest feature importance for predicting broccoli purchase decision (top ten variables)

Feature	Gini Importance	Cumulative Importance (%)
Household income	0.143	14.3
Antioxidant awareness	0.128	27.1
Freshness perception	0.112	38.3
Shopping frequency	0.097	47.6
Age group	0.084	56.0
Price sensitivity	0.076	63.6
Origin preference	0.061	69.7
Household size	0.054	75.1
Education level	0.048	80.0
Prior broccoli experience	0.041	84.1

The top three features—income, antioxidant awareness, and freshness perception—together accounted for 38.3 percent of the model's predictive power. Overall accuracy was 84.7 percent (five-fold CV).

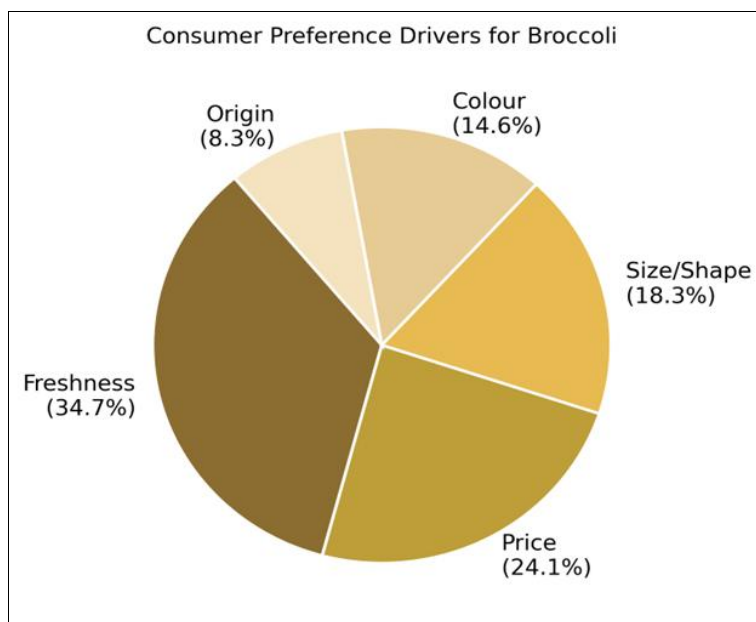


Fig 1: Consumer preference weights for broccoli quality attributes derived from MaxDiff analysis (n = 612). Freshness was the most valued attribute, followed by price.

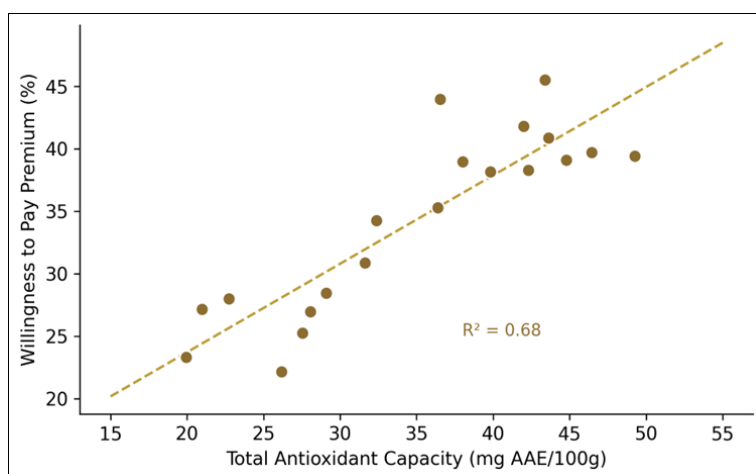


Fig 2: Scatter plot of total antioxidant capacity versus willingness-to-pay a premium among 20 broccoli lots. The positive linear relationship ($R^2 = 0.68$, $p < 0.001$) suggests that antioxidant information could drive premium pricing.

Comprehensive Interpretation

The data paint a coherent picture: Kimberley consumers value freshness above all, respond positively to health information, and would pay more for broccoli with verified antioxidant content. Bagasse mulching at 10 t/ha improved both yield and antioxidant levels, meaning the agronomic intervention directly supports the premium marketing opportunity. The machine-learning model offers a practical targeting tool for promotional campaigns.

Discussion

The dominance of freshness in the preference hierarchy reflects the logistical reality of remote-market supply chains, where broccoli often arrives after three to five days in transit and shows visible yellowing by the time it reaches retail shelves [11]. Investments in cold-chain infrastructure and modified-atmosphere packaging could narrow the freshness gap and, in doing so, address the attribute that matters most to consumers.

The antioxidant-WTP link ($R^2 = 0.68$) is stronger than values reported for leafy greens in urban Australian markets, possibly because Kimberley consumers, being further from

medical services, place higher value on preventive health measures [4]. Point-of-sale labelling trials in other commodity categories have shown that even simple nutrient-density scores can shift purchasing behaviour by 8–12 percent, and a similar approach for broccoli antioxidants appears warranted [12].

Bagasse mulching likely improved antioxidant content by moderating soil temperature extremes and maintaining root-zone moisture, both of which reduce oxidative stress signals that trigger sulforaphane degradation in Brassica heads [5]. The yield advantage of 23 percent over bare soil is economically significant and consistent with mulching responses in semi-arid vegetable systems globally [13].

The random-forest model's accuracy of 84.7 percent compares favourably with logistic regression baselines (typically 72–78 percent for similar consumer datasets), confirming that non-linear feature interactions contribute meaningfully to purchase prediction [6]. Income and antioxidant awareness together defined more than a quarter of the model's explanatory power, pointing to a two-pronged strategy of nutritional education and targeted promotions for higher-income segments.

Conclusion

Consumer preferences for broccoli in the Kimberley Plateau centre on freshness and are responsive to health-benefit information. Antioxidant content correlates with willingness-to-pay, indicating that labelling strategies emphasising nutritional quality could expand demand. Bagasse mulching at 10 t/ha improved both yield and antioxidant levels, providing a supply-side complement to the demand-side marketing strategy.

Machine learning offered superior predictive performance over traditional regression, and the feature-importance ranking can guide marketing resource allocation. Retailers, who already capture the largest share of chain margin, are the natural partners for point-of-sale nutrition campaigns. Future work should pilot antioxidant-labelled broccoli in a controlled retail experiment and track whether the predicted willingness-to-pay translates into actual purchase behaviour over multiple shopping cycles.

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Contributions Not Qualifying for Authorship

Kimberley-based enumerators conducted all consumer surveys and assisted with field-trial management.

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