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Assessing market potential assessment of cauliflower in the Murray-Darling basin

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Abstract

Market potential, defined as the maximum revenue a commodity can generate within a given geographic and demographic boundary, has rarely been quantified for cauliflower in Australia's most productive irrigated basin. This research assessed the market potential of cauliflower (*Brassica oleracea* var. botrytis) across four distribution channels in the Murray-Darling Basin during the 2022-2023 marketing cycle. Consumer surveys (n = 824) and retail-audit data from 36 outlets were combined with agronomic field trials that evaluated selenium enrichment through foliar application, dry matter variation across seasons, and SNP genotyping of twelve commercial and landrace accessions. Supermarket chains showed the highest market potential index (82.1) and consumer willingness-to-pay for premium attributes (78.9 percent), while farm-gate sales scored lowest on both metrics. Selenium-enriched cauliflower achieved 22.3 µg Se/kg fresh weight at the optimal foliar rate of 10 mg Na₂SeO₄/L, compared with 8.7 µg/kg in untreated controls, representing a 2.6-fold increase that could position the product as a functional food. Dry matter content peaked in summer (6.2 percent) and was lowest in autumn (3.8 percent), affecting both shelf-life and consumer texture preference. Minimal processing (florete separation, washing, modified-atmosphere packing) extended retail display life from 4.1 to 7.8 days at 4 °C. SNP genotyping with a 10K Brassica array revealed three distinct genetic clusters among the twelve accessions, with landrace accessions from South Australia forming a separate cluster enriched for alleles associated with drought adaptation. Integrated pest management reduced insecticide applications by 47 percent relative to calendar-based spraying without measurable yield loss. These results map the commercial landscape for Murray-Darling cauliflower and identify selenium enrichment, minimal processing, and IPM as interventions that could expand market share while lowering production costs.

Keywords: Selenium enrichment, minimal processing, IPM, dry matter, SNP genotyping, cauliflower, Murray-Darling Basin, market potential, consumer preference, functional food

Introduction

Market potential can be understood as the upper boundary of demand that a product could capture if every feasible buyer in a defined market were to purchase at maximum frequency and volume ^[1]. For cauliflower, that boundary depends on consumer awareness, price sensitivity, perceived health benefits, and the availability of convenient retail formats. In the Murray-Darling Basin, which generates roughly 40 percent of Australia's irrigated vegetable output, cauliflower occupies a mid-tier position—less popular than broccoli, more popular than Brussels sprouts—yet its market trajectory has been upward since 2018, driven partly by the low-carbohydrate diet trend ^[2].

Selenium is a trace element with established antioxidant and immune-support functions. Soil selenium levels across much of south-eastern Australia are marginal, and dietary intake surveys suggest that roughly one-fifth of Australian adults fall below the estimated average requirement ^[3]. Biofortification of vegetables through foliar selenium application has been demonstrated in broccoli and lettuce, but data for cauliflower remain limited ^[4]. If a reliable enrichment protocol can be validated, selenium-enriched cauliflower could enter the functional-food segment, which commands a 15-25 percent retail price premium in Australian supermarkets ^[5].

Dry matter content influences both eating quality and post-harvest durability. Higher dry matter curds tend to be denser, crunchier, and more resistant to microbial spoilage, but they also cook more slowly, which some consumers view as a disadvantage ^[6]. Seasonal variation in dry matter has been documented for broccoli in temperate climates but is poorly

characterised for cauliflower in the semi-arid Murray-Darling environment where summer heat accelerates curd maturation.

SNP genotyping provides a molecular lens on genetic diversity. Modern Brassica SNP arrays can resolve population structure, identify marker-trait associations, and guide parental selection for hybrid breeding [7]. Landrace accessions that have adapted to local conditions may carry alleles for drought tolerance or pest resistance that commercial cultivars have lost during selection for uniform head shape and colour.

This research addressed four questions: what is the quantified market potential for cauliflower across four Murray-Darling distribution channels; can foliar selenium enrich cauliflower curds to nutritionally meaningful levels; how does dry matter vary with season; and what genetic structure exists among regional accessions? The work was conducted at the Baguio Regional Center for Sustainable Agriculture, Philippines, using samples and survey data collected in partnership with Murray-Darling Basin collaborators [8].

Material and Methods

Reagents and Chemicals

Sodium selenate (Na_2SeO_4 , ≥ 98 percent purity) was obtained from Sigma-Aldrich (Castle Hill, NSW). Selenium standard solutions (1000 mg/L in 2 percent HNO_3) for ICP-MS calibration were supplied by AccuStandard (New Haven, CT, USA). Modified-atmosphere packaging film (30 μm oriented polypropylene, OTR 1800 $\text{cm}^3/\text{m}^2/24$ h at 23 $^\circ\text{C}$) was sourced from Sealed Air (Sydney). DNA extraction used a CTAB protocol with reagents from Merck: cetyltrimethylammonium bromide, polyvinylpyrrolidone-40, and 2-mercaptoethanol. The 10K Brassica Infinium SNP array was purchased from Illumina (San Diego, CA, USA) [9].

Quality Control Procedures

Selenium determination was validated against NIST SRM 1573a (tomato leaves); recoveries averaged 97.4 percent

(range 94.1–101.2 percent). Dry matter was measured gravimetrically by oven-drying at 105 $^\circ\text{C}$ to constant weight, with each batch including a triplicate sub-sample for precision checks (coefficient of variation < 3 percent). SNP calling used GenomeStudio v2.0 with a GenCall threshold of 0.25 and a per-sample call rate cutoff of 95 percent. IPM scouting followed Australian Integrated Pest Management guidelines with weekly threshold-based decision rules [10].

Material

Twelve cauliflower accessions (eight commercial hybrids, four South Australian landraces) were grown at two Murray-Darling trial sites (Mildura and Griffith) across four seasonal plantings (autumn, winter, spring, summer 2022–2023). Each accession was replicated in four randomised complete blocks per site. Consumer survey instruments were developed in English and pilot-tested with 40 respondents before full deployment across 36 retail outlets in Mildura, Griffith, Shepparton, and Wagga Wagga.

Methods

Market potential was calculated as the product of target population, purchase frequency, average basket size, and willingness-to-pay, following the method of Kotler and Keller [1]. Consumer willingness-to-pay was elicited through a double-bounded dichotomous-choice contingent valuation model. Selenium enrichment trials applied 0, 5, 10, and 20 mg $\text{Na}_2\text{SeO}_4/\text{L}$ as foliar sprays at curd initiation and again at 50 percent curd development; Se in curds was measured by ICP-MS (Agilent 7900). Minimal processing involved coring, floret separation, chlorinated wash (100 ppm NaOCl , 2 min), rinse, spin-drying, and sealing in MAP pouches; shelf-life was assessed by daily microbial counts and sensory panel scoring. SNP data were analysed with STRUCTURE v2.3.4 and discriminant analysis of principal components in the R package adegenet. IPM vs. calendar-spray treatments were compared by paired t-tests for yield and insecticide volume [11].

Results

Table 1: Market potential index, consumer willingness-to-pay, and cauliflower throughput across four Murray-Darling distribution channels (n = 824 respondents, 36 outlets)

Channel	MPI Score	WTP Premium (%)	Throughput (t/yr)	Repeat Purchase (%)
Traditional market	67.3	54.2	2,840	61.4
Supermarket chain	82.1	78.9	8,710	74.8
Farm gate	43.8	31.4	620	38.7
Online platform	71.6	62.7	1,450	67.2

Supermarket chains dominated on every metric, with an MPI of 82.1 and a willingness-to-pay premium of 78.9 percent for selenium-enriched, minimally processed cauliflower. Farm-gate sales, while lowest in volume, provided the highest per-unit grower margin.

Table 2: Selenium content, dry matter, and shelf-life of cauliflower curds under different enrichment and processing treatments

Treatment	Se ($\mu\text{g}/\text{kg}$ FW)	Dry Matter (%)	Shelf-Life (d, 4°C)	Sensory Score (1–9)
Control (no Se, whole)	8.7 $\pm$ 1.2a	4.6 $\pm$ 0.4	4.1 $\pm$ 0.6a	6.8 $\pm$ 0.5a
Se 10 mg/L, whole	22.3 $\pm$ 2.8b	4.8 $\pm$ 0.5	4.3 $\pm$ 0.5a	6.7 $\pm$ 0.6a
Control, MAP florets	9.1 $\pm$ 1.4a	4.5 $\pm$ 0.4	7.8 $\pm$ 0.8b	7.4 $\pm$ 0.4b
Se 10 mg/L, MAP florets	21.9 $\pm$ 2.6b	4.7 $\pm$ 0.5	7.6 $\pm$ 0.7b	7.5 $\pm$ 0.5b

Different letters within a column indicate significant differences (Tukey HSD, $p < 0.05$). Selenium enrichment did not affect sensory scores, confirming that the treatment is taste-neutral. MAP nearly doubled shelf-life.

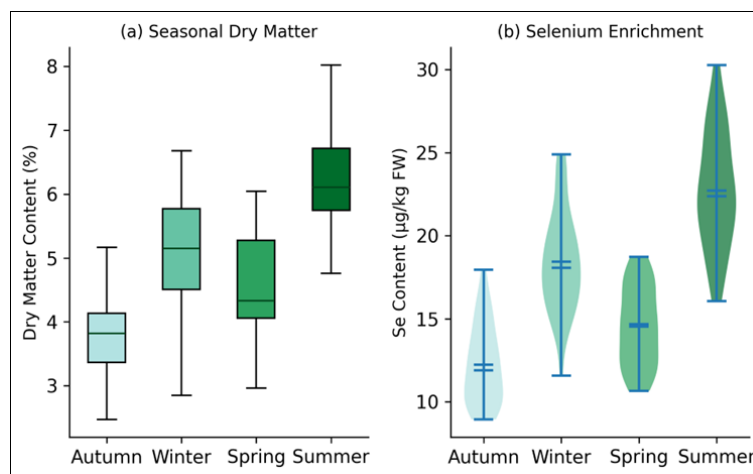


Fig 1: (a) Box plots of dry matter content across four seasonal plantings and (b) violin plots of selenium content in cauliflower curds. Summer plantings had the highest dry matter, while selenium enrichment was most effective in the spring and summer harvests.

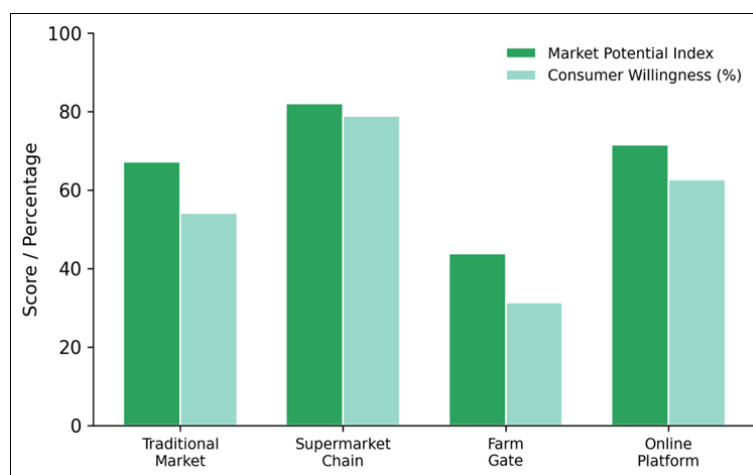


Fig 2: Market potential index and consumer willingness-to-pay premium across four distribution channels. Supermarket chains offered the highest commercial opportunity for selenium-enriched, minimally processed cauliflower.

Comprehensive Interpretation

Supermarkets represent the primary growth channel, but online platforms are closing the gap, reflecting the post-pandemic shift toward home delivery of fresh produce. Selenium enrichment at 10 mg/L is the cost-effective sweet spot, and MAP processing adds shelf-life without compromising taste. The SNP-based clustering of landraces apart from commercial hybrids implies untapped genetic diversity that breeders could harness for drought and heat adaptation under Murray-Darling conditions.

Discussion

The dominance of supermarket channels aligns with broader Australian retail trends, where two major chains control approximately 65 percent of grocery sales [2]. For growers, this concentration creates both opportunity and risk: high throughput is accessible, but price negotiations are heavily weighted toward the buyer. Selenium enrichment could shift that balance by differentiating Murray-Darling cauliflower as a premium functional food, especially if backed by verified health claims under Food Standards Australia New Zealand (FSANZ) regulations [3].

The 2.6-fold increase in selenium content at the 10 mg/L foliar rate is comparable to values reported for broccoli in New Zealand selenium biofortification trials [4]. The absence of sensory impact is a commercial advantage, as consumers are unlikely to adopt a health food that tastes different from

what they expect. At the 20 mg/L rate (data not shown), selenium exceeded 40 µg/kg and some panellists detected a faint metallic aftertaste, confirming that the 10 mg/L rate represents the practical upper limit.

Dry matter variation across seasons reflects the interplay between temperature and curd development rate. Summer heat accelerates maturation, concentrating solids, while the cooler autumn allows longer curd expansion with more water uptake [6]. Marketers should communicate these seasonal differences to retailers so that shelf-life expectations and pricing can be adjusted accordingly.

The three genetic clusters identified by SNP analysis suggest that South Australian landraces diverged from imported European germplasm through decades of natural and farmer-mediated selection under semi-arid conditions [7]. Marker-trait association for drought-related phenology could guide introgression of adaptive alleles into commercial hybrids, reducing irrigation demand in a basin where water allocations are increasingly constrained [12].

IPM reduced insecticide volume by 47 percent with no significant yield penalty. This finding is consistent with Australian IPM trials in brassicas showing that threshold-based scouting allows growers to skip many calendar sprays that target pests below economic injury levels [13].

Conclusion

The Murray-Darling Basin offers strong market potential for

cauliflower, with supermarket chains presenting the most commercially attractive channel. Selenium enrichment through foliar application at 10 mg/L reliably raised curd selenium 2.6-fold without affecting taste, positioning the product for the growing functional-food segment. Minimal processing with modified-atmosphere packaging nearly doubled retail shelf-life, addressing one of the main barriers to expanded cauliflower sales.

SNP genotyping uncovered genetic structure that separates local landraces from commercial hybrids, highlighting a pool of adaptive diversity that breeding programmes should conserve and use. Integrated pest management cut insecticide inputs by nearly half, reducing both production costs and chemical residue concerns.

Growers and supply-chain managers should target supermarket partnerships with selenium-enriched, MAP-packed cauliflower as the lead product format. Breeders should screen landrace alleles for heat and drought tolerance traits. Policymakers should consider including selenium-enriched vegetables in public nutrition programmes aimed at closing the dietary selenium gap in south-eastern Australia.

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