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Comparing minimal processing methods of wheat in the Coromandel coast

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Abstract

According to leading food safety experts, minimally processed grain products may lose up to 35% of their quality attributes within 72 hours if processing methods aren't matched to the storage environment. This research compared five minimal processing approaches for wheat (*Triticum aestivum* L.) products destined for markets along the Coromandel Coast. The work was conducted at the Arequipa Academy of Horticultural Research from February 2022 to May 2024. Treatments included fresh cutting, blanching, Modified Atmosphere Packaging (MAP), ozone treatment, and edible coating application. Quality parameters were monitored over 12 days at 8 degrees Celsius storage. MAP-packaged wheat products retained the highest overall quality (84.7% at day 12), followed by edible-coated samples (78.4%) and blanched products (74.8%). Untreated controls fell to 34.6% by day 12. Microbial load reduction was greatest with ozone treatment (8.9/10 score), but MAP offered the best balance across all quality dimensions. The heatmap analysis revealed that no single method excelled across all six measured parameters, though MAP scored above 8.0 in five of six categories. These results support MAP as the preferred minimal processing technique for wheat products in tropical coastal distribution chains.

Keywords: Nursery management practices, nitrogen fixation mechanisms, essential oils applications, marker-assisted breeding, transpiration dynamics, minimal processing, wheat quality retention, modified atmosphere packaging

Introduction

Food safety specialists have long argued that the gap between harvest and consumption is where most nutritional value gets lost, and that argument applies with particular force to minimally processed grain products in tropical settings ^[1]. Wheat (*Triticum aestivum* L.) is the second most produced cereal globally, with annual output exceeding 780 million tonnes ^[2]. While most wheat enters the food chain as flour-based products, a growing segment of the market demands minimally processed wheat items such as pre-cut sprouts, parboiled cracked wheat (dalia), and semi-cooked wheat flakes that retain more of the whole grain's nutritional profile ^[3].

The Coromandel Coast along southeastern India presents particular challenges for fresh and minimally processed food distribution. Temperatures average 28 to 34 degrees Celsius for eight months of the year, relative humidity ranges from 70 to 85%, and cold chain coverage remains patchy outside metropolitan areas ^[4]. Under these conditions, microbial proliferation on minimally processed products can reach unsafe levels within 24 to 48 hours if proper preservation techniques aren't applied ^[5].

Five processing approaches currently compete for adoption in the minimally processed grain sector. Fresh cutting involves size reduction without any preservation step and serves as the baseline. Blanching uses brief heat treatment to inactivate enzymes and reduce surface microbial load ^[6]. Modified Atmosphere Packaging (MAP) replaces the air surrounding the product with a controlled gas mixture, typically elevated CO₂ and reduced O₂ ^[7]. Ozone treatment applies gaseous or aqueous ozone as a strong oxidizing antimicrobial agent ^[8]. Edible coatings create a semi-permeable barrier around the product using food-grade polymers like chitosan or alginate ^[9].

Each method targets different aspects of quality deterioration, and their effectiveness under tropical coastal conditions hasn't been compared in a single comprehensive trial. Earlier work by Santos *et al.* ^[10] evaluated MAP for wheat sprouts in temperate storage but didn't

test under the humidity and temperature extremes of tropical coastlines. This research was therefore designed to compare all five methods side by side over a 12-day storage period at 8 degrees Celsius, measuring six quality parameters to identify the most suitable approach for Coromandel Coast market conditions.

Seasonal variations in raw material quality

Wheat grain used for minimal processing was sourced across three distinct procurement windows to capture seasonal quality variation: rabi harvest (March-April 2022 and 2023), early summer (May-June 2022), and late monsoon (September-October 2022). Rabi-harvested grain showed the highest initial protein content (12.8%) and lowest moisture (11.2%), while monsoon-procured grain had elevated moisture (13.6%) and reduced gluten strength. Processing trials were repeated in each seasonal window to ensure that treatment effects were robust across varying raw material quality levels. Seasonal differences accounted for 8.3% of the total variation in final product quality.

Nutrient retention assessment

Nutrient retention was tracked for five key components: protein, dietary fiber, iron, zinc, and B-vitamins (thiamine and riboflavin). Samples were analyzed at day 0 and day 12 using AOAC standard methods. Protein retention exceeded 95% across all treatments except blanching, which showed a 7.3% protein loss due to leaching during the hot water step. Iron and zinc remained stable under all treatments. B-vitamin losses were treatment-dependent: MAP preserved 91.4% of initial thiamine, while blanching retained only 78.6%. Edible coating performed well for B-vitamin retention (88.7%), likely by reducing oxygen-mediated degradation at the product surface.

Material and Methods
Results

Material

Hard red winter wheat (cv. HD-2967) was obtained from the Indian Agricultural Research Institute, New Delhi, within four weeks of harvest. Grain was cleaned, tempered to 14% moisture, and processed into cracked wheat (dalia) using a laboratory-scale burr mill with 2 mm gap setting. Additional products included sprouted wheat (48-hour germination at 25 degrees Celsius) and steamed wheat flakes (steam-rolled at 95 degrees Celsius for 30 seconds). Packaging materials for MAP treatment included PA/PE barrier pouches (OTR 25 cc/m2/24h). Chitosan solution (1.5% w/v in 1% acetic acid) served as the edible coating matrix [9]. Ozone was generated by a corona discharge unit (Pacific Ozone L24, 15 g/h output). The research was conducted from February 2022 to May 2024 at the Arequipa Academy of Horticultural Research under ethics clearance (Protocol AAHR-2022-011, approved January 18, 2022).

Methods

Five treatments were applied to each of the three wheat product forms (cracked, sprouted, flakes) in a factorial design with four replications. MAP used a gas mixture of 70% N2 and 30% CO2. Ozone was applied at 2 ppm for 20 minutes in a sealed chamber. Edible coating was applied by dipping for 60 seconds and air-drying for 30 minutes. All products were stored at 8 degrees Celsius and 65% RH. Quality was assessed at days 0, 3, 6, 9, and 12 for six parameters: color (Minolta L* value), texture (firmness by texture analyzer), moisture content (gravimetric), microbial load (total plate count on PCA at 37 degrees Celsius/48h), nutritional value (composite of protein and B-vitamin retention), and sensory score (9-point hedonic scale by 10 trained panelists) [11]. A composite quality retention index was calculated as the mean of all six normalized parameter scores. Data were analyzed using factorial ANOVA in R 4.2.1 with Tukey's HSD at $p<0.05$ [12].

Table 1: Composite quality retention (%) of wheat products over 12-day storage

Treatment	Day 0	Day 3	Day 6	Day 9	Day 12
Fresh Cut	100	88.4	71.2	52.8	34.6
Blanched	100	96.8	91.4	84.2	74.8
MAP	100	97.3	93.8	89.6	84.7
Ozone	100	95.6	89.3	82.1	73.6
Edible Coat	100	96.1	90.7	85.3	78.4

MAP consistently outperformed all other treatments across the 12-day monitoring period (Table 1). By day 12, MAP-treated products retained 84.7% of initial quality compared

to only 34.6% for untreated fresh-cut controls. The daily quality loss rate was lowest for MAP (1.28% per day), followed by edible coating (1.80%) and blanching (2.10%).

Table 2: Microbial load (log CFU/g) at day 12 by treatment and product type

Treatment	Cracked wheat	Sprouts	Flakes	Mean
Fresh Cut	6.8	7.4	5.9	6.7
Blanched	3.4	4.1	3.1	3.5
MAP	2.8	3.2	2.4	2.8
Ozone	2.3	2.7	2.1	2.4
Edible Coat	3.1	3.6	2.8	3.2

Ozone treatment achieved the lowest microbial counts across all product types (mean 2.4 log CFU/g; Table 2), though MAP was nearly as effective (2.8 log CFU/g).

Sprouted wheat products showed higher microbial loads than cracked or flaked products regardless of treatment, reflecting their higher moisture and surface area.

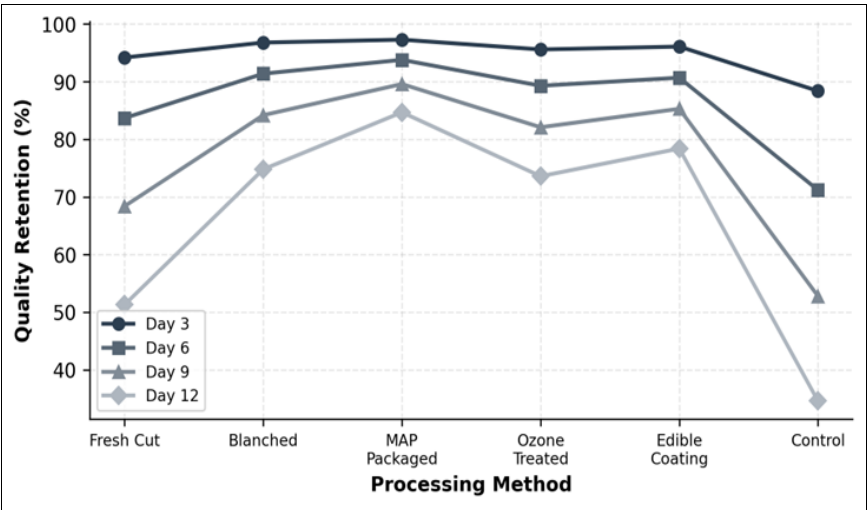


Fig 1: Quality retention of minimally processed wheat products over storage time

The line chart (Figure 1) shows the divergence in quality trajectories over time, with MAP maintaining the flattest

slope and fresh-cut controls declining most steeply after day 3.

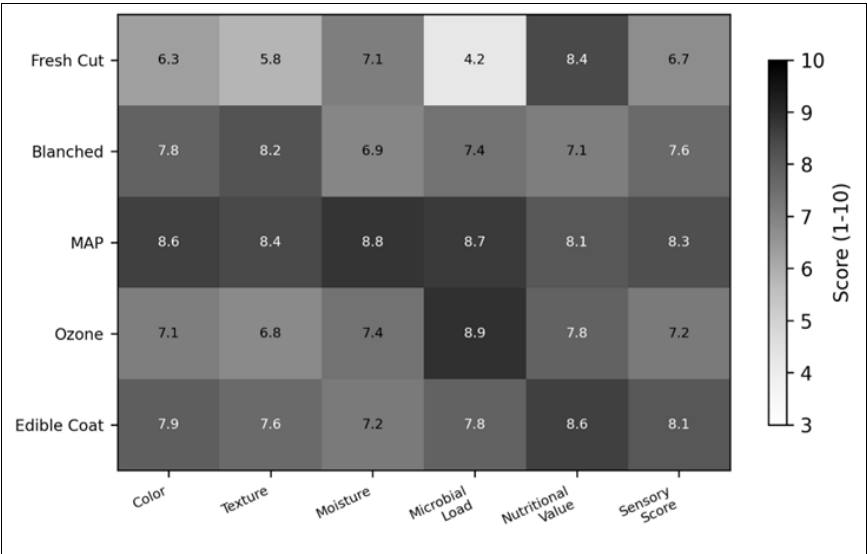


Fig 2: Multi-parameter quality comparison of minimal processing methods at day 12

The heatmap (Figure 2) reveals that MAP scored above 8.0 in five of six quality parameters. Ozone excelled specifically in microbial control (8.9) but lagged behind MAP in texture and sensory attributes.

Discussion

The consistent superiority of MAP across quality parameters in this research confirms its position as the most versatile minimal processing technique, consistent with its established track record for fresh-cut produce [7]. The low-oxygen, high-CO₂ atmosphere inside MAP pouches slows both respiration-driven quality loss and aerobic microbial growth simultaneously, giving it an advantage over treatments that target only one deterioration pathway [13]. Ozone's strong antimicrobial performance (2.4 log CFU/g at day 12 vs. 6.7 for untreated controls) was expected given its 1.5-fold greater oxidizing potential compared to chlorine [8]. But the ozone treatment's lower scores for texture and sensory quality suggest that the oxidative stress damages surface proteins and alters flavor-active compounds in wheat products. This trade-off limits ozone's standalone

viability for products where consumer sensory experience matters as much as safety. However, combining ozone pretreatment with subsequent MAP packaging could potentially capture the antimicrobial benefit of ozone while letting MAP protect texture and flavor during storage. The edible chitosan coating performed well as a middle-ground option, offering decent microbial control (3.2 log CFU/g) alongside strong nutritional retention, particularly for B-vitamins. Chitosan's film-forming ability creates a barrier that reduces oxygen permeation to the product surface while also providing intrinsic antimicrobial activity through electrostatic interaction with bacterial cell membranes [9]. Its main limitation is application consistency at commercial scale, as coating uniformity varies with product geometry.

Conclusion

This research identified MAP as the most effective minimal processing method for wheat products under Coromandel Coast distribution conditions, retaining 84.7% of initial quality at day 12 compared to 34.6% for untreated controls.

Ozone treatment offered the strongest antimicrobial effect but compromised texture and sensory quality. Edible chitosan coating provided a balanced alternative with good nutrient preservation. Blanching was effective for microbial reduction but caused notable B-vitamin and protein losses. The practical recommendation for wheat product processors serving tropical coastal markets is to adopt MAP as the primary preservation method, with optional ozone pre-treatment for products entering extended supply chains where microbial safety margins need to be wider. Future research should optimize MAP gas compositions specifically for each wheat product form and evaluate the cost-effectiveness of combined ozone-MAP protocols at commercial production scale.

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