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Effect of dry salt and brine treatments on physicochemical responses of Appemidi mango genotypes

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Abstract
The present study was done to evaluate the effects of dry salt and brine preservation on twenty Appemidi mango genotypes traditionally used for pickle making in the Western Ghats of Karnataka. Tender fruits were collected at the pickle stage and subjected to two curing methods: dry salting, where fruits were layered with coarse salt in a 1:1 ratio, and brining, where fruits were immersed in a saturated salt solution containing 25-30% NaCl. After six months of curing period, four qualitative parameters-colour after preservation, fermentation intensity, final stabilized colour and shrinkage, were assessed visually. The results revealed clear genotype-specific responses and marked differences between the two treatments. Dry salt consistently caused uniform browning in almost all genotypes, while brine preserved yellowish green colour in thirteen types and resulted in browning in seven, indicating variability in pigment stability. Fermentation intensity under dry salt remained mostly medium, whereas brine supported strong fermentation in thirteen genotypes and medium fermentation in the remaining seven. Final stabilized colour after six months showed a strong predominance of browning under dry salt, with only four genotypes retaining yellow, while brine produced an equal distribution of light yellow and brown colour among genotypes. Shrinkage was uniformly high under dry salt due to rapid dehydration, whereas brine resulted in low, medium and high shrinkage categories, with medium shrinkage dominating and only two genotypes showing high shrinkage. Overall, the study demonstrates that preservation behaviour in Appemidi mangoes is strongly influenced by genotype as well as curing method, enabling targeted utilization of specific types based on colour stability, fermentation behaviour and structural integrity for diverse pickle products.

Keywords: Appemidi mango, salt curing, brine preservation, fermentation, shrinkage, colour stability

Introduction

Aromatic pickle mango represents a distinct group of wild *Mangifera indica* types harvested extensively from the central Western Ghats by local rural communities due to their pronounced and characteristic fragrance. These undomesticated, small-sized, highly aromatic fruit types are locally known as “appemidi” in Kannada, a term that translates to “aromatic, tiny, unripe mango” (Vasudeva *et al.*, 2014) [6]. In contrast to commercial table mango cultivars, appemidi fruits possess an intense sourness, rendering them unsuitable for consumption as fresh edible flesh but highly valued for traditional pickle preparation. These fruits are harvested at a very immature stage and are highly valued for their exceptional aroma, firm texture, thin peel and remarkable ability to absorb salt and spices, making them ideal for traditional pickle preparation (Ashine *et al.*, 2015) [4]. Their specialized use, deep-rooted cultural heritage and strong geographical identity have resulted in their recognition under the Geographical Indication registry, emphasizing their uniqueness and regional importance. Rural communities across Uttara Kannada, Shivamogga and surrounding regions have preserved traditional knowledge related to their collection, handling and curing for generations, making Appemidi mangoes both a biological and cultural asset (Veena and Dinesh, 2018) [3].

Past studies and documentation have highlighted the enormous diversity among Appemidi landraces with respect to physico-chemical characteristics, peel thickness, resin content and volatile aromatic compounds.

These inherent differences significantly influence their behaviour during curing, especially in terms of colour stability, firmness, fermentation dynamics and final pickle quality. Variability in traits such as moisture content, cuticular thickness and phenolic composition suggests that each genotype may respond differently to salt-based preservation, thereby affecting the quality and acceptability of the final product. Despite this recognized diversity, comprehensive scientific evaluation of genotype-specific preservation responses remains limited. Much of the existing information is anecdotal, based on traditional knowledge rather than systematic experimentation.

Preservation of tender mangoes prior to spice incorporation is a critical step in ensuring the long-term stability, safety and sensory quality of pickle products. Two principal curing methods—dry salting and brining—have been traditionally practiced across the region. Dry salting involves layering mangoes with coarse salt, promoting rapid osmotic dehydration and tissue firming. This method often results in intense moisture loss, which can influence texture and pigment changes. Brining, on the other hand, involves immersion of fruits in concentrated salt solution, facilitating gradual salt penetration and supporting controlled microbial fermentation. Research on vegetable fermentation has shown that the method and concentration of salt greatly influence microbial growth, enzymatic reactions, pigment degradation and organic acid formation, all of which shape the final sensory profile. However, little scientific work has been undertaken to understand how different Appemidi genotypes behave under these two preservation methods. Most available literature focuses on general pickle fermentation or physico-chemical traits of mangoes, without specifically addressing the unique Appemidi group (Naik, 2015) [5]. The research gap lies in the lack of comparative, genotype-level evaluation of preservation outcomes such as colour retention, fermentation intensity, shrinkage behaviour and final stabilized appearance. Since the commercial pickle industry increasingly demands uniform, high-quality raw material, identifying genotypes best suited for specific preservation methods has become essential. Moreover, the absence of such scientific data limits the potential for standardization, value addition and conservation of genetically diverse Appemidi landraces. Therefore, the present study was undertaken to systematically compare the effects of dry salt and brine treatments on twenty Appemidi mango genotypes. By evaluating key preservation-related characters-colour changes after treatment, fermentation or odour intensity, stabilized colour and shrinkage patterns—the study aims to generate evidence-based insights into the preservation behaviour of each genotype.

Materials and Methods

The present study was conducted to assess the effects of dry salt and brine treatments on twenty Appemidi mango genotypes traditionally used for pickle preparation in the Western Ghats of Karnataka, including Sadamidi, Kashimidi, Balanjimidi, Shirakuli-2, Keladhi Matadha Jeerige, Hekkalamane Appe 2, Gundi Gadde Appe 1, Palaaragadde, Madaralli, Kalligadde Appe, Suloor Appe Kinase Appe, Chikka Bengali, Isgoor Appe, Balikoppa Appe, Murgeer, Appemidi, Khasimidi, Karpura Jeerige, Chasi and Jeerige Neermausi. Tender fruits harvested at the traditional pickle stage were washed, surface dried and immediately subjected to two preservation methods, namely dry salting and brining. In the dry salt method, fruits were arranged in alternating layers with coarse salt at a 1:1 ratio (w/w) and stored in airtight containers under ambient laboratory conditions, whereas in the brine method, fruits were completely immersed in a saturated salt solution containing 25-30% NaCl and kept under identical storage conditions. Both treatments were maintained for a curing period six month, after which the fruits were evaluated for four key preservation-related traits, namely the colour of appemidi after preservation, fermentation or odour intensity (categorised as low, medium or strong), final stabilized colour and the degree of shrinkage (recorded as low, medium or high). All observations were recorded through careful visual assessment by trained evaluators using standard procedures commonly employed in traditional curing and processing units to ensure consistency and reliability of the qualitative parameters measured.

Result and Discussion

The effects of dry salt and brine treatments on the twenty Appemidi mango genotypes showed clear and consistent patterns across all four evaluated parameters, although the degree of response varied considerably among genotypes (Table 1). The observations recorded for colour after preservation, fermentation or odour intensity, stabilized colour, and shrinkage revealed significant genotype-specific differences that reflected the underlying physiological and biochemical traits of each type.

Colour of Appemidi after Preservation

Dry salt treatment caused a uniform trend of browning across nearly all genotypes. From Sadamidi to Jeerige Neermausi, the fruits developed a brown or darkened surface, indicating intense dehydration and oxidative changes. Even genotypes that naturally retained lighter peel colour, such as Khasimidi and Balanjimidi, shifted to brown under dry salt conditions. Only one genotype, Isgoor Appe, did not turn brown and instead remained yellowish green, demonstrating exceptional resistance to browning under osmotic stress. This uniformity in browning suggested that rapid moisture withdrawal and concentration of internal compounds were dominant processes during dry salting. In contrast, brine treatment showed significant changes in results. Among twenty genotypes, thirteen genotypes maintained a yellowish green appearance after preservation, including Sadamidi, Kashimidi, Balanjimidi, Shirakuli-2, Gundi Gadde Appe 1, Balikoppa Appe, Murgeer, Appemidi, Khasimidi, Karpura Jeerige, Chasi and Jeerige Neermausi. These genotypes appeared visually fresher compared to their dry-salted counterparts. While seven genotypes, such as Keladhi Matadha Jeerige, Hekkalamane Appe 2, Palaaragadde, Madaralli, Kalligadde Appe, Suloor Appe Kinase Appe and Chikka Bengali, turned brown even under brine, showing that their pigment stability was naturally lower.

The uniform browning observed in most Appemidi genotypes under dry salt treatment can be attributed to rapid osmotic dehydration, which disrupts cellular membranes and brings polyphenol oxidase (PPO) and phenolic substrates into direct contact, resulting in enzymatic oxidation and formation of brown melanins (Mayer, 2006; Tomás-Barberán & Espín, 2001) [1, 7]. Concentration of phenolics during dehydration further accelerates browning. The exceptional retention of yellowish-green colour in

Isgoor Appe suggests inherently lower PPO activity, reduced phenolic content or stronger antioxidant defences. Under brine conditions, slower salt diffusion helps maintain membrane integrity, limiting enzyme-substrate interactions and thereby reducing browning (Serra, 2021) [2]. However, genotypes such as Keladhi Matadha Jeerige and Hekkalamane Appe 2 still browned, indicating naturally higher PPO levels or less stable chlorophyll pigments (Tomás-Barberán and Espín, 2001) [7]. Thus, genotype-specific differences in enzymatic activity, pigment stability and cellular structure primarily governed the colour results.

Fermentation/Odour Development

Fermentation intensity varied distinctly between the two preservation methods. Under dry salt, the fermentation level was consistently medium for almost all genotypes. The only exception was Appemidi and Karpura jeerige showed a comparatively lower fermentation intensity. This uniform medium-level fermentation under dry salt indicated controlled microbial activity facilitated by high salt concentration and reduced moisture availability.

Fermentation intensity under brine treatment showed clear genotype-wise differentiation. A total of 13 genotypes exhibited strong fermentation, namely Kashimidi, Balanjimidi, Shirakuli-2, Keladhi Matadha Jeerige, Hekkalamane Appe 2, Gundi Gadde Appe 1, Madaralli, Kalligadde Appe, Isgoor Appe, Balikoppa Appe, Khasimidi, Chasi and Jeerige Neermausi. These genotypes developed a pronounced fermented odour, indicating vigorous microbial activity during brining. In contrast, 7 genotypes displayed medium fermentation, including Sadamidi, Palaaragadde, Suloor Appe Kinase Appe, Chikka Bengali, Murgeer, Appemidi and Karpura Jeerige. None of the genotypes showed low fermentation under brine. This distribution highlights that a majority of Appemidi genotypes tend to support strong lactic fermentation in brine, while a smaller subset ferments at a moderate level due to inherent biochemical or structural characteristics.

Final Colour after Stabilization

The final stabilized colour of the mangoes showed distinct patterns influenced by the preservation method. After six months of dry salt storage, the genotypes showed two distinct final color categories—yellow and brown—with a clear predominance of browning. A total of 4 genotypes retained a yellow stabilized color, namely Sadamidi, Kashimidi, Shirakuli-2 and Kalligadde Appe, indicating relatively better pigment retention despite dehydration. In contrast, 16 genotypes developed a brown stabilized color, including Balanjimidi, Keladhi Matadha Jeerige, Hekkalamane Appe 2, Gundi Gadde Appe 1, Palaaragadde, Madaralli, Suloor Appe Kinase Appe, Chikka Bengali, Isgoor Appe, Balikoppa Appe, Murgeer, Appemidi, Khasimidi, Karpura Jeerige, Chasi and Jeerige Neermausi. The large number of genotypes turning brown suggests that prolonged dehydration under dry salt strongly promotes pigment oxidation and browning reactions across most Appemidi types.

Brine treatment resulted in two major stabilized color categories—light yellow and brown—with noticeable variation among genotypes. A total of 10 genotypes retained a light yellow color after six months, including Kashimidi, Balanjimidi, Shirakuli-2, Keladhi Matadha Jeerige, Palaaragadde, Kalligadde Appe, Suloor Appe Kinase Appe, Isgoor Appe, Karpura Jeerige and Jeerige Neermausi. These genotypes showed comparatively better pigment preservation under brine conditions. In contrast, 10 genotypes developed a brown stabilized color, namely Sadamidi, Hekkalamane Appe 2, Gundi Gadde Appe 1, Madaralli, Chikka Bengali, Balikoppa Appe, Murgeer, Appemidi, Khasimidi and Chasi. The equal distribution between the two categories indicates that pigment stability during brining is strongly genotype-dependent, with some genotypes maintaining chlorophyll-derived hues while others undergoing significant browning despite the controlled moisture environment. The dominance of brown coloration after dry salt storage can be attributed to severe osmotic dehydration, which accelerates chlorophyll degradation and activates oxidative pathways. As cell membranes collapse, chlorophyll is rapidly converted to pheophytins and pheophorbides, resulting in loss of green/yellow pigments (González-Aguilar, 2017) [8]. Simultaneously, exposure of phenolic substrates to polyphenol oxidase (PPO) promotes enzymatic browning, explaining why 16 genotypes shifted to brown despite genetic variability (Sommano *et al.*, 2020) [9]. The four yellow-retaining genotypes likely possess higher pigment stability or reduced PPO activity.

Under brine, the more balanced distribution between light yellow and brown stabilized colors reflects slower dehydration and partial preservation of chlorophyll due to milder osmotic stress and reduced oxygen exposure (Yang *et al.*, 2024) [10]. Genotypes retaining light yellow may have inherently stronger chlorophyll-binding proteins or lower oxidative enzyme activity, whereas brown-forming types may possess higher chlorophyllase or PPO activity. Thus, final colour stabilization is strongly genotype-dependent, governed by pigment metabolism and oxidative susceptibility.

Shrinkage Responses

Shrinkage showed the significant differences between the two treatments. Under dry salt, all genotypes displayed high shrinkage, with no exceptions. This reflected rapid and substantial moisture removal, causing the fruits to become significantly wrinkled and reduced in size. High shrinkage was consistent across genotypes such as Sadamidi, Kashimidi, Balanjimidi, Kalligadde Appe, Chikka Bengali and others, demonstrating that dry salt produces strong dehydration effects irrespective of genotype.

Shrinkage levels under brine preservation showed three distinct categories-low, medium and high-with medium shrinkage being the dominant response among genotypes. Among all genotypes, 2 genotypes exhibited low shrinkage, namely Sadamidi and Balanjimidi, indicating better size retention and minimal tissue collapse during the brining process. In contrast, 16 genotypes showed medium shrinkage, including Kashimidi, Shirakuli-2, Keladhi Matadha Jeerige, Hekkalamane Appe 2, Gundi Gadde Appe 1, Palaaragadde, Madaralli, Suloor Appe Kinase Appe, Isgoor Appe, Balikoppa Appe, Murgeer, Appemidi, Khasimidi, Karpura Jeerige, Chasi and Jeerige Neermausi. These genotypes experienced moderate dehydration, characteristic of gradual osmotic water movement in brine.

The markedly high shrinkage observed in all genotypes under dry salt treatment can be explained by the intense osmotic gradient created by direct contact with solid salt. Rapid water efflux from epidermal and mesocarp tissues leads to severe plasmolysis, collapse of cell walls and loss of turgor, resulting in pronounced wrinkling and volume reduction. Such accelerated dehydration is characteristic of high-salt environments where moisture is rapidly drawn out of plant tissues (Vasugi *et al.*, 2008) [12]. Because this process is largely physical and not genotype-dependent, all twenty genotypes exhibited uniformly high shrinkage.

In contrast, brine treatment produced more moderated shrinkage responses. The slower osmotic flow in liquid brine preserved membrane integrity for a longer duration, reducing tissue collapse and allowing many genotypes to maintain structural firmness. Medium shrinkage in sixteen genotypes indicates controlled dehydration, while the low-shrinkage genotypes likely possess thicker cuticles or higher moisture-binding capacity (Ahmad *et al.*, 2025) [11]. The two high-shrinkage genotypes suggest increased sensitivity to osmotic stress or inherently lower internal moisture. The shrinkage results clearly show that brine preservation provides more flexibility, allowing classification of genotypes into low, medium and high-shrinkage groups, which enables targeted use in different pickle products. Dry salt is suitable only when uniform high firmness is needed. This categorization can help processors, farmers and industries select the most appropriate genotype based on the desired pickle type and market demand.

Table 1: Effect of dry salt and brine treatment on appemidi mangoes

	Genotypes	Color of appemidi after preservation		Fermented/Odour		Color		Shrinkage	
		Dry Salt	Brine	Dry Salt	Brine	Dry Salt	Brine	Dry Salt	Brine
1.	Sadamidi	Brown	Yellowish Green	Medium	Medium	Yellow	Brown	High	Low
2.	Kashimidi	Brown	Yellowish Green	Medium	Strong	Yellow	Light Yellow	High	Medium
3.	Balanjimidi	Brown	Yellowish Green	Medium	Strong	Brown	Light Yellow	High	Low
4.	Shirakuli-2	Brown	Yellowish Green	Medium	Strong	Yellow	Light Yellow	High	Medium
5.	Keladhi matadha jeerige	Brown	Brown	Medium	Strong	Brown	Light Yellow	High	Medium
6.	Hekkalamane appe 2	Brown	Brown	Medium	Strong	Brown	Brown	High	Medium
7.	Gundi Gadde appe 1	Brown	Yellowish Green	Medium	Strong	Brown	Brown	High	Medium
8.	Palaaragadde	Brown	Brown	Medium	Medium	Brown	Light Yellow	High	Medium
9.	Madaralli	Brown	Brown	Medium	Strong	Brown	Brown	High	Medium
10.	Kalligadde appe	Brown	Brown	Medium	Strong	Yellow	Light Yellow	High	High
11.	Suloor appe kinase appe	Brown	Brown	Medium	Medium	Brown	Light Yellow	High	Medium
12.	Chikka Bengali	Brown	Brown	Medium	Medium	Brown	Brown	High	High
13.	Isgoor appe	Yellowish Green	Yellowish Green	Medium	Strong	Yellow	Light Yellow	High	Medium
14.	Balikoppa appe	Brown	Yellowish Green	Medium	Strong	Brown	Brown	High	Medium
15.	Murgeer	Brown	Yellowish Green	Medium	Medium	Brown	Brown	High	Medium
16.	Appemidi	Brown	Yellowish Green	Low	Medium	Brown	Brown	High	Medium
17.	Khasimidi	Brown	Yellowish Green	Medium	Strong	Brown	Brown	High	Medium
18.	Karpura jeerige	Brown	Yellowish Green	Low`	Medium	Brown	Light Yellow	High	Medium
19.	Chasi	Brown	Yellowish Green	Medium	Strong	Brown	Brown	High	Medium
20.	Jeerige Neermausi	Brown	Yellowish Green	Medium	Strong	Brown	Brown	High	Medium

Conclusion

The study demonstrates that dry salt and brine preservation methods elicit distinctly different physiological and visual responses in Appemidi mango genotypes. Dry salt induced uniform browning, strong dehydration and consistently high shrinkage across all genotypes, whereas brine allowed greater variation, preserving colour, moderating shrinkage and enhancing fermentation in several types. Genotype-specific differences in pigment stability, enzymatic activity and structural integrity shaped the final quality outcomes. These findings highlight the importance of selecting appropriate genotypes based on the desired pickle characteristics. Brine-treated mangoes offer greater flexibility for premium and fermented products, while dry-salted fruits suit traditional preparations requiring firm texture.

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