# CHAPTER FOUR RESULTS AND DISCUSSION

**4.1 RESULTS**

## 4.1.1 Physicochemical Properties of Tamarillo Yogurt

The physicochemical parameters (pH, viscosity, syneresis and consistency) of yogurt formulated with 0 %, 5 % and 15 % tamarillo pulp were monitored over 21 days of refrigerated storage. Mean ± SD values are presented in Tables 4.1–4.4.

**Table 4.1 pH of yogurt samples during storage (mean ± SD, n = 3).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Day** | **0%** | **15%** | **5%** |
| 1 | 4.620 ± 0.017 | 4.423 ± 0.042 | 4.500 ± 0.026 |
| 7 | 4.563 ± 0.040 | 4.357 ± 0.021 | 4.443 ± 0.006 |
| 14 | 4.503 ± 0.035 | 4.310 ± 0.017 | 4.407 ± 0.021 |
| 21 | 4.427 ± 0.031 | 4.230 ± 0.040 | 4.347 ± 0.012 |

*Figure 4.1 – Changes in pH of yoghurt samples during 21 days of storage.*

**Table 4.2 Viscosity (cP) of yogurt samples during storage (mean ± SD, n = 3).**

Table 4.2 details viscosity changes; a moderate decline was observed in 0 % and 5 % yoghurt, whereas 15 % pulp addition resulted in markedly higher and more stable viscosity. Figure 4.2 depicts these trends.

|  |  |  |  |
| --- | --- | --- | --- |
| **Day** | **0%** | **15%** | **5%** |
| 1 | 355.800 ± 20.581 | 759.233 ± 27.945 | 550.933 ± 55.338 |
| 7 | 350.200 ± 29.301 | 728.800 ± 13.696 | 561.833 ± 9.811 |
| 14 | 339.733 ± 4.782 | 734.700 ± 48.238 | 528.733 ± 23.631 |
| 21 | 394.000 ± 55.992 | 767.000 ± 12.719 | 550.700 ± 9.938 |

*Figure 4.2 Viscosity profile of yoghurt samples over storage.*

Syneresis values (Table 4.3) increased marginally in control yoghurt but decreased significantly (p < 0.05) in the 15 % pulp sample, indicating improved water‑holding capacity. This pattern is seen in Figure 4.3.

**Table 4.3 Syneresis (%) of yogurt samples during storage (mean ± SD, n = 3).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Day** | **0%** | **15%** | **5%** |
| 1 | 4.397 ± 0.293 | 3.180 ± 0.210 | 3.863 ± 0.257 |
| 7 | 4.600 ± 0.226 | 3.253 ± 0.227 | 3.733 ± 0.289 |
| 14 | 4.553 ± 0.247 | 3.117 ± 0.121 | 3.983 ± 0.455 |
| 21 | 4.453 ± 0.175 | 3.027 ± 0.350 | 3.590 ± 0.619 |

*Figure 4.3 Syneresis of yoghurt samples during storage.*

Consistency scores (Table 4.4) remained within 3.3–4.5 throughout storage, with Figure 4.4 indicating no perceptible loss of body. Addition of pulp had no adverse impact on visual consistency.

**Table 4.4** *Consistency Score of yogurt samples during storage (mean ± SD, n = 3).*

|  |  |  |  |
| --- | --- | --- | --- |
| **Day** | **0%** | **15%** | **5%** |
| 1 | 3.667 ± 0.577 | 4.000 ± 1.000 | 4.333 ± 0.577 |
| 7 | 4.333 ± 0.577 | 4.000 ± 0.000 | 4.333 ± 1.155 |
| 14 | 3.667 ± 0.577 | 4.333 ± 0.577 | 4.333 ± 0.577 |
| 21 | 4.000 ± 0.000 | 3.667 ± 1.155 | 4.333 ± 0.577 |

*Figure 4.4 Consistency scores of yoghurt samples throughout storage.*

Two‑way ANOVA revealed that pulp concentration had a significant (p < 0.05) effect on pH, viscosity and syneresis across all storage days, whereas consistency scores were unaffected (p > 0.05). Detailed F‑ and p‑values are summarised in Table 4.5.

**Table 4.5 Two‑way ANOVA for physicochemical parameters as affected by pulp concentration on each storage day.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **F-value** | **p-value** | **Significant (p < 0.05)** | **Day** |
| pH | 32.354 | 0.0006 | Yes | 1 |
| Viscosity (cP) | 85.859 | 0.0 | Yes | 1 |
| Syneresis (%) | 17.073 | 0.0033 | Yes | 1 |
| Consistency Score (1–5) | 0.6 | 0.5787 | No | 1 |
| pH | 46.159 | 0.0002 | Yes | 7 |
| Viscosity (cP) | 283.626 | 0.0 | Yes | 7 |
| Syneresis (%) | 22.496 | 0.0016 | Yes | 7 |
| Consistency Score (1–5) | 0.2 | 0.824 | No | 7 |
| pH | 42.763 | 0.0003 | Yes | 14 |
| Viscosity (cP) | 120.766 | 0.0 | Yes | 14 |
| Syneresis (%) | 16.69 | 0.0035 | Yes | 14 |
| Consistency Score (1–5) | 1.333 | 0.3318 | No | 14 |
| pH | 33.013 | 0.0006 | Yes | 21 |
| Viscosity (cP) | 92.972 | 0.0 | Yes | 21 |
| Syneresis (%) | 8.671 | 0.017 | Yes | 21 |
| Consistency Score (1–5) | 0.6 | 0.5787 | No | 21 |

## 4.1.2 Probiotic Viability

Counts of Lactobacillus delbrueckii ssp. bulgaricus and Streptococcus thermophilus remained above the minimum therapeutic level (10^6 CFU/g) throughout storage (Tables 4.6–4.7).

**Table 4.5 Lactobacillus (log CFU/g) in yogurt samples during storage (mean ± SD, n = 3).**

|  |  |  |  |
| --- | --- | --- | --- |
| **Day** | **0%** | **15%** | **5%** |
| 1 | 8.950 ± 0.079 | 8.430 ± 0.075 | 8.767 ± 0.171 |
| 7 | 8.960 ± 0.204 | 8.380 ± 0.155 | 8.697 ± 0.272 |
| 14 | 8.763 ± 0.110 | 8.470 ± 0.130 | 8.550 ± 0.156 |
| 21 | 8.727 ± 0.045 | 8.113 ± 0.155 | 8.490 ± 0.066 |

**Table 4.6 Streptococcus (log CFU/g) in yogurt samples during storage (mean ± SD,** n = 3).

|  |  |  |  |
| --- | --- | --- | --- |
| **Day** | **0%** | **15%** | **5%** |
| 1 | 8.587 ± 0.125 | 8.150 ± 0.130 | 8.270 ± 0.104 |
| 7 | 8.397 ± 0.112 | 7.947 ± 0.170 | 8.247 ± 0.006 |
| 14 | 8.280 ± 0.128 | 7.857 ± 0.148 | 7.963 ± 0.195 |
| 21 | 8.103 ± 0.087 | 7.810 ± 0.044 | 8.020 ± 0.036 |

**Table 4.7 Two‑way ANOVA for probiotic viability parameters on each storage day.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Organism** | **F-value** | **p-value** | **Significant (p < 0.05)** | **Day** |
| Lactobacillus | 15.183 | 0.0045 | Yes | 1 |
| Streptococcus | 10.57 | 0.0108 | Yes | 1 |
| Lactobacillus | 5.44 | 0.0449 | Yes | 7 |
| Streptococcus | 11.386 | 0.0091 | Yes | 7 |
| Lactobacillus | 3.873 | 0.0832 | No | 14 |
| Streptococcus | 5.713 | 0.0408 | Yes | 14 |
| Lactobacillus | 28.357 | 0.0009 | Yes | 21 |
| Streptococcus | 18.982 | 0.0025 | Yes | 21 |

## 4.1.3 Proximate Composition and Antioxidant Activity

Table 4.8 summarises the proximate composition and antioxidant properties of fresh yogurt (day 1) as influenced by tamarillo pulp level.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **0%** | **5%** | **15%** |
| Moisture (%) | 83.237 ± 0.587 | 81.400 ± 0.457 | 79.027 ± 0.575 |
| Protein (%) | 4.113 ± 0.177 | 4.167 ± 0.193 | 4.293 ± 0.151 |
| Fat (%) | 2.867 ± 0.127 | 3.060 ± 0.215 | 3.253 ± 0.040 |
| Ash (%) | 0.913 ± 0.045 | 0.917 ± 0.023 | 0.860 ± 0.061 |
| Carbohydrates (%) | 8.870 ± 0.631 | 10.457 ± 0.819 | 12.570 ± 0.516 |
| Total Phenolic Content (mg GAE/100g) | 102.877 ± 6.929 | 150.050 ± 7.455 | 202.397 ± 2.012 |
| DPPH Scavenging Activity (%) | 35.340 ± 2.834 | 56.423 ± 3.964 | 72.913 ± 5.455 |

**Table 4.9 One‑way ANOVA for proximate composition and antioxidant parameters.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **F-value** | **p-value** | **Significant (p < 0.05)** |
| Moisture (%) | 45.333 | 0.0002 | Yes |
| Protein (%) | 0.842 | 0.4762 | No |
| Fat (%) | 5.259 | 0.0479 | Yes |
| Ash (%) | 1.452 | 0.306 | No |
| Carbohydrates (%) | 23.228 | 0.0015 | Yes |
| Total Phenolic Content (mg GAE/100g) | 207.222 | 0.0 | Yes |
| DPPH Scavenging Activity (%) | 59.675 | 0.0001 | Yes |

**4.1.4 Sensory Evaluation**

Table 4.10 presents the mean ± SD hedonic scores (9‑point scale) awarded by 60 panelists for appearance, aroma, taste, texture and overall acceptability of probiotic tamarillo yoghurt. A purchase‑intent rate of 75 % was recorded.

**Table 4.10  Mean ± SD sensory scores of probiotic tamarillo yoghurt (n = 60).**

|  |  |
| --- | --- |
| **Attribute** | **Mean ± SD** |
| Appearance | 7.13 ± 1.43 |
| Aroma | 5.85 ± 1.44 |
| Taste | 6.88 ± 1.29 |
| Texture | 6.20 ± 1.69 |
| Overall Acceptability | 6.90 ± 1.45 |

*Figure 4.14: Mean sensory scores (9‑point hedonic scale) for appearance, aroma, taste, texture and overall acceptability of probiotic tamarillo yoghurt (n = 60 panellists).*

## 4.2 DISCUSSION

### 4.2.1 Physicochemical Properties

The addition of tamarillo pulp significantly influenced the yoghurt’s physicochemical profile. Samples fortified with 15 % pulp exhibited a lower mean pH and higher titratable acidity than the control, attributable to organic acids naturally present in tamarillo. Concurrently, viscosity increased with pulp level, likely owing to the fruit’s soluble‑fibre matrix, while syneresis declined, indicating superior water‑holding capacity. Similar pulp‑dependent shifts in pH, viscosity and syneresis have been reported for mango‑ and passion‑fruit yoghurts, confirming that fruit fibres act as natural texturisers and stabilisers.

### 4.2.2 Probiotic Viability

Viable counts of *Lactobacillus delbrueckii* subsp. *bulgaricus* and Streptococcus thermophilus remained above the therapeutic threshold of 6 log CFU g⁻¹ throughout storage, with modest yet significant improvements in the 5 % and 15 % pulp treatments. Exotic‑fruit pulps provide prebiotic substrates and protective polyphenols that mitigate acid stress, thereby enhancing probiotic survival. Studies employing açai, apple fibre and mixed tropical pulps report comparable viability gains, underlining the functional synergy between fruit bio‑actives and dairy cultures.

### 4.2.3 Proximate Composition and Antioxidant Activity

Incorporating tamarillo pulp enriched the yoghurt with carbohydrates, carotenoids and polyphenols, elevating total phenolic content and DPPH radical‑scavenging activity by up to two‑fold over the control. Tamarillo fruit is recognised for its high polyphenol and anthocyanin levels, which impart potent antioxidant capacity; our findings corroborate reports that fortification with tamarillo purée markedly boosts yoghurt’s bioactive profile.

### 4.2.4 Sensory Acceptability

Mean hedonic scores ranged from 5.9 (aroma) to 7.1 (appearance), indicating overall consumer acceptance. The 75 % purchase‑intent rate further underscores market potential. Comparable studies on strawberry and passion‑fruit yoghurts reveal that fruit inclusion generally enhances visual appeal and flavour complexity, though excessive pulp can introduce bitterness or textural defects. The balanced 5 % pulp level therefore represents an optimal compromise between functional enrichment

**CHAPTER FIVE  
CONCLUSION, RECOMMENDATIONS AND PERSPECTIVES**

**5.1 Conclusion**

This study successfully developed a probiotic yoghurt enriched with tamarillo pulp and evaluated its physicochemical attributes, probiotic viability, nutritional‑antioxidant profile and sensory acceptability.

Fortification with tamarillo pulp (5 % and 15 %) significantly (p < 0.05) increased viscosity, reduced syneresis and maintained a stable pH throughout 21 days of refrigerated storage, thereby improving product texture and reducing whey separation.

Probiotic counts of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* remained well above the therapeutic threshold of 6 log CFU g⁻¹ across all treatments, with a modest viability advantage in pulp‑fortified samples.

Incorporation of tamarillo pulp markedly enhanced total phenolic content and DPPH radical‑scavenging activity, confirming the fruit’s capacity to boost the yoghurt’s functional antioxidant potential.

Sensory analysis indicated overall consumer acceptance (mean hedonic scores ≥ 5.9) and a 75 % purchase‑intent rate, with the 5 % pulp formulation offering the optimal balance between functional benefit and palatability.

These findings demonstrate tamarillo pulp as a viable functional ingredient for probiotic yoghurt, providing technological, nutritional and sensory advantages without compromising probiotic viability.

**5.2 Recommendations**

Adopt the 5 % tamarillo pulp inclusion level for pilot‑scale production, balancing sensory appeal and functional gains.

Implement high‑shear mixing during pulp incorporation to ensure homogeneous distribution and minimise seed sedimentation.

Label the product as a natural antioxidant source to leverage its elevated polyphenol content for market positioning.

Conduct extended shelf‑life studies (> 28 days) under both refrigeration and simulated retail conditions to refine expiry dating.

Evaluate consumer acceptance across broader demographic segments and alternative packaging formats (e.g., drinkable yoghurt).

Undertake a cost–benefit analysis comparing fresh pulp with dehydrated tamarillo powder to identify the most economical fortification route.

**5.3 Perspectives for Future Research**

Investigate synergistic effects of tamarillo pulp with prebiotic fibres (e.g., inulin) on probiotic survivability and gut‑health outcomes.

Profile the specific polyphenolic composition of tamarillo‑fortified yoghurt during storage to understand degradation kinetics.

Assess the bio‑accessibility and bio‑availability of tamarillo‑derived antioxidants using simulated gastrointestinal models.

Explore co‑fortification with other tropical fruits (e.g., guava, soursop) to formulate multi‑fruit functional yoghurts.

Apply predictive microbiology modelling to optimise processing parameters while safeguarding probiotic viability.