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RESEARCH ARTICLE

Paneer whey-apricot drink: Effect of bentonite treatment and aging, and comparative sensory evaluation

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Abstract: This study explored the impact of varying bentonite concentrations and aging on the physico-chemical properties and comparative sensory analysis of *paneer* whey-apricot wine (PWAW) with whey wine (WW), apricot wine (AW) and a commercial apricot wine (MAW). Wine namely WW (without apricot) and AW (without whey) were considered as control samples. The results revealed that the light transmittance of PWAW treated with 1% bentonite was significantly higher (89.75%) compared to the untreated samples (80.81%) ($p<0.05$). However, increasing concentration of bentonite resulted in significant reduction in total solids, total soluble solids, total and reducing sugars ($p<0.05$). Bentonite at 0.2% did not have any significant effect on the ethanol content ($p<0.05$). Further, its use at 0.5% and above did not have any significant effect on the lightness value (L^*) of PWAW samples ($p>0.05$). Aging resulted in slight but significant decrease in total soluble solids, total phenolics, ethanol and DPPH activity ($p<0.05$). However, the L^* was found to significantly increase from 75.89 to 77.01 at the end of 30 days of aging ($p<0.05$). Comparison of different wines revealed that the L^* value of WW (98.80), AW (78.88), PWAW (75.89), and MAW (70.43) were found to be in decreasing order. Further, PWAW was found to have significantly high amount of total phenolics, ABTS and DPPH activity levels compared to MAW, AW, and WW ($p<0.05$). Sensory evaluation revealed that the overall score of PWAW was significantly higher compared to AW and WW ($p<0.05$). Particularly, aroma and bouquet, acetic acid (vinegary), total acidity, flavour, and general quality scores of PWAW samples were found to be significantly higher compared to AW and WW samples ($P<0.05$). This study revealed the role of bentonite treatment (0.5%) in providing better clarity to PWAW. Also, the study highlighted the superior antioxidant activity and sensory scores of PWAW compared to AW, WW and MAW samples.

Keywords: Aging, Apricot wine, Bentonite, *Paneer* whey, Sensory evaluation, Whey wine

Introduction

Fruit wines are renowned for their delightful taste and numerous health benefits. In 2023, they achieved a market value of US $ 182.6 million, indicating a substantial growth in demand for fruit wines in India. This growth is projected to continue at a remarkable rate of 14.99 % (MOFPI, 2023). The clarity of fruit wines is crucial for their sensory acceptability. Bentonite is employed to enhance wine clarity by reducing haziness (Kumar and Suhag, 2024; Maslov Bandić et al. 2022). It is a clay mineral called montmorillonite. When wine proteins interact with it, they form a complex that settles down in the fermenter's base. This deposit accounts for nearly 3 to 10% of the wine's volume (Kumar and Suhag, 2024; Liu et al. 2023). However, it's important to note that adding too much bentonite can negatively impact the sensory properties of wine (Maslov Bandić et al. 2022).

Local brands in India offer a diverse range of fruit wines, utilizing seasonal fruits like plums, apricots, peaches, apples, strawberries, cherries, and pears. Notably, Himachal Pradesh, a significant contributor to India's total fruit wine production (as reported by the Ministry of Food and Public Distribution in 2023), is home to numerous brands that produce apricot wines using their locally sourced apricots, which are renowned for their exceptional sensory acceptability. However, the apricots of the Ladakh region, a unique territory within India, have yet to be fully explored for wine production, despite receiving the prestigious geographical indication status.

In the global dairy industry, there's a constant drive to utilize the various types of whey generated in a low-energy, cost-effective, and environmentally friendly manner. Paneer whey, which dominates the Indian dairy industry, is the focus of ongoing

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efforts to optimize its utilization. Researchers have attempted to convert cheese whey into wine, but the presence of a milky flavor hindered its popularity. To enhance its sensory profile, fruit flavors were added to successfully increase the acceptability of whey wine. Additionally, aging wine improves its sensory qualities beyond other factors. During aging, the residual sugars in wine are consumed by their microflora, contributing to the desired flavor (Carpena et al. 2020; Abrol et al. 2019). The amount of residual sugar varies depending on the type of yeast strains used in alcoholic fermentation. Zhang et al. (2024) found that *Saccharomyces* species dominate the final phase of primary fermentation. Waterhouse et al. (2016) reported that esters are formed during a reaction between carboxylic acids and wine alcohols, which are volatile compounds that contribute to the wine's flavor and aroma, especially in aged wines.

In earlier studies, the author group successfully developed *paneer* whey-apricot pulp-based wine (PWAW). However, they encountered a limitation: the wine became hazy or cloudy during storage. To address this issue, the present study was aimed to optimize the levels of bentonite to achieve excellent clarity in PWAW while minimizing the impact on its alcohol and flavor components. Additionally, the clarified PWAW was aged for one month alongside AW and WW to assess the effect of aging on the wine's quality.

Materials and Methods

Materials

Apricots were sourced from the local market of Leh and its surrounding areas, including Saspol and Alchi in Ladakh. Paneer whey was collected from the Experimental Dairy Plant of the ICAR-National Dairy Research Institute in Karnal, Haryana. Commercial apricot wine (MAW) sample was obtained from the local market of Kullu in Himachal Pradesh, India. All AR/GR grade chemicals, microbiological media, and enzymes used in the study were procured from reputable suppliers, including M/s CDH Chemicals, M/s Hi-Media, and M/s SRL Chemicals in India. Granulated sucrose was purchased from the local Karnal market. Pectinase enzyme obtained from *Aspergillus niger* was procured from M/s SRL Chemicals in India. It exhibited an activity of 3.5 U/mg at 4°C. Yeast cultures, *Saccharomyces cerevisiae* (NCDC 45) and *Kluyveromyces marxianus* (NCDC 39) strains, were obtained from the National Collection of Dairy Culture (NCDC) of NDRI in Karnal, Haryana. *Saccharomyces cerevisiae* has been used as a starter yeast in wine production for last several decades (Gonzalez and Morales, 2022). However, it cannot ferment lactose due to its inability to produce β-galactosidase (Zou et al. 2021). *Kluyveromyces marxianus*, commonly isolated from dairy products, is better known for its high lactose assimilating capacity (Lane and Morrissey, 2010). Hence, for this this study we used both the yeasts.

Preparation of paneer whey-apricot wine

Paneer whey was defatted using a cream separator at 40-50°C and deproteinized at 85°C for 30 minutes. The "must" was prepared by mixing whey and apricot pulp in a predetermined ratio (1-5:5-1) and adding pectinase at 0.5%. Sucrose was added to raise the TSS to 24°B, and the pH was adjusted to 4.5 using a citric acid solution (2%). Sodium benzoate was added to chemically sterilize the "must." At lower concentrations, sodium benzoate does not affect the wine fermentation and reduces the risk of off-flavours production during storage of wine (Joshi and Joshi, 2014). Yeast co-cultures (1:1) were inoculated and incubated at 28°C. Fermentation was completed when carbon dioxide production ceased. Siphoning was done, and bentonite treatment was applied to eliminate suspended particles from the wine. The fresh wine was bottled, capped, and pasteurized at 63°C for 30 minutes. Further details on the optimization process of PWAW could be obtained from Jindal et al. (2025). Whey wine (WW) and apricot wine (AW) were prepared as controls and were prepared using the optimized method. WW was made from a blend of paneer whey and water (in the same quantity as apricot pulp in case of PWAW), while AW was made from a blend of apricots and water. All wine samples were aged at 10°C for a month.

Optimization of the level of bentonite for clarification treatment.

The effect of varying bentonite concentrations (0.2%, 0.5%, and 1%) on the PWAW wine's clarity was investigated. Bentonite was thoroughly blended into the wine samples and left undisturbed for 2 to 3 hours. Subsequently, it was centrifuged at 5500 rpm for 20 minutes to remove the solids, resulting in a clear liquid. The optimum bentonite concentration for clarifying PWAW was determined by subjecting the samples to physico-chemical analysis, including color intensity and light transmittance. The total soluble solids (TSS) content was recorded using a hand refractometer (Make: ERMA) (0-32°B) at 20°C and expressed in °Brix. Ethanol (FSSAI 13.003:2021) and methanol (FSSAI 13.028:2021) contents were determined by gas chromatography-mass spectroscopy. The titratable acidity (expressed in % maleic acid) (FSSAI 13.008:2021), volatile acidity (expressed in % acetic acid) (FSSAI 13.009:2021), total sugars (FSSAI 13.037:2021) by Fehling's solution method, reducing sugars (FSSAI 13.035:2021) by DNS method, were determined using methods provided by the FSSAI (FSSAI Manual Analysis Alcoholic Beverages, 2021). Total esters (FSSAI 13.010:2021), total phenolic content (Folin–Ciocalteu method using the gallic acid as a standard) (Tarko et al. 2020), antioxidant activity in terms of DPPH (Balthazar et al. 2019), and ABTS (Balthazar et al. 2019), mineral content, light transmittance (Ma et al. 2020), and color values (Hunter colorlab colorimeter) were also determined. Colour values were expressed in terms of lightness-darkness (L^*), redness-greenness (a^*), and yellowness-blueness (b^*) where

L^* is 0 (darkness) to 100 (lightness), a^* -60 (greenness) to +60 (redness) and b^* -60 (blueness) to +60 (yellowness).

Aging and sensory evaluation of wine samples

The PWAW was aged along with WW and AW in dark-colored glass bottles at 10°C for one month without any disturbance. The physico-chemical properties of aged wine were analysed during the aging period. The sensory evaluation of different levels of bentonite treated paneer whey-apricot wine (PWAW) samples, optimized PWAW, WW, and AW was conducted with a total of 20 semi-trained judges, who assessed the wine samples using Davis 20-point scorecard (Langstaff, 2010). Davis 20-point score card consisted of attributes such as appearance (2), colour (2), aroma and bouquet (4), acetic acid (vinegary) (2), total acidity (2), sweetness (1), body/mouth feel (1), flavour (2), bitterness and astringency (2) and general quality (2) with the maximum score for each attribute given in parenthesis. WW and AW were used as a control to compare the sensory acceptability of PWAW. Artificial daylight-type illumination and constant ambient temperature (22°C) were maintained during sensory evaluation of the samples. RO water was used for rinsing before testing each sample. Samples were served to judges in wine glasses, each containing 20 mL of wine at 10°C. Each sample was coded with 3-digit random numbers, and the order in which judges tested wines was randomized.

Statistical analysis

In the present study, all the experiments were carried out in triplicate and the data obtained was expressed in mean values with corresponding standard deviation. One-way ANOVA was used to investigate the effects of varying levels of bentonite on the physico-chemical and sensory attributes of PWAW, WW, and AW using IBM SPSS software (ver. 20). Duncan's post-hoc test was applied to draw meaningful inferences among the different treatments. However, in case of comparison of the different wines (WW or AW or PWAW) before and after aging, respective wines were subjected to paired t-test.

Results and Discussion

Effect of different levels of bentonite on the physico-chemical properties of the paneer whey-apricot wine

The effect of different levels of bentonite on the physico-chemical properties of *paneer* whey-apricot wine (PWAW) is given in Table 1. Light transmission in wine refers to the amount of light that can pass through the wine when it is exposed to light source. It is a measure of the wine's clarity and colour intensity. It can be seen that with increasing concentration of bentonite, the percentage light transmission increased from 80.81% in control to 89.75% in wine samples (PWAW) treated with 1% bentonite. However, significant differences were observed among samples

Table 1: Effect of various levels of bentonite on the physico-chemical properties of the *paneer* whey-apricot wine

Parameter	Bentonite Level			
	0%	0.2%	0.5%	1.0%
Lightness value (L^*)	$73.06^{c}\pm0.06$	$75.10^{b}\pm0.05$	$76.89^{a}\pm0.07$	$76.92^{a}\pm0.05$
Redness-Greenness (a^*)	$5.76^{a}\pm0.09$	$5.62^{b}\pm0.08$	$5.28^{c}\pm0.05$	$4.92^{d}\pm0.06$
Yellowness-Blueness (b^*)	$52.93^{a}\pm0.17$	$52.79^{a}\pm0.03$	$52.38^{a}\pm0.05$	$50.60^{b}\pm0.05$
Light Transmittance (%)	$80.81^{b}\pm0.413$	$85.9^{b}\pm0.52$	$89.97^{a}\pm0.12$	$89.75^{a}\pm0.39$
Color intensity (absorbance)	$0.398^{a}\pm0.001$	$0.352^{b}\pm0.001$	$0.350^{b}\pm0.002$	$0.310^{c}\pm0.006$
pH	$4.42^{a}\pm0.01$	$4.45^{a}\pm0.03$	$4.44^{a}\pm0.04$	$4.46^{a}\pm0.04$
Total Soluble Solids (°B)	$9.07^{a}\pm0.058$	$8.73^{b}\pm0.058$	$8.53^{c}\pm0.115$	$8.23^{d}\pm0.058$
Total Solids (%)	$9.29^{a}\pm0.03$	$9.11^{b}\pm0.074$	$8.90^{c}\pm0.061$	$8.70^{d}\pm0.036$
Total sugars (%)	$3.85^{a}\pm0.03$	$3.75^{b}\pm0.02$	$3.75^{b}\pm0.01$	$3.44^{c}\pm0.02$
Reducing sugars (%)	$3.71^{a}\pm0.04$	$3.63^{b}\pm0.02$	$3.42^{c}\pm0.02$	$3.29^{d}\pm0.015$
Titratable acidity (% MA)	$0.468^{a}\pm0.002$	$0.450^{a}\pm0.001$	$0.442^{a}\pm0.003$	$0.420^{a}\pm0.002$
Volatile Acidity (%AA)	$0.019^{a}\pm0.001$	$0.018^{a}\pm0.001$	$0.017^{a}\pm0.001$	$0.015^{a}\pm0.001$
Ash (%)	$0.547^{a}\pm0.015$	$0.520^{b}\pm0.009$	$0.505^{c}\pm0.004$	$0.489^{d}\pm0.004$
Ethanol (%)	$12.91^{a}\pm0.04$	$12.85^{ab}\pm0.03$	$12.82^{b}\pm0.06$	$12.72^{c}\pm0.04$
Methanol (%)	*BLQ	*BLQ	*BLQ	*BLQ
Total phenols (mg GAE/L)	$272.47^{a}\pm1.11$	$261.2^{b}\pm1.74$	$254.63^{c}\pm1.27$	$135.3^{d}\pm1.6$
Total esters (g/L of absolute alcohol)	$123.4^{b}\pm2.64$	$127.69^{a}\pm2.6$	$123.9^{b}\pm1.69$	$125.03^{ab}\pm3.68$

Mean ± SD (n=3).

^{a,b,c,d} Mean values with different superscript letters in same row differ significantly ($p<0.05$).

MA: maleic acid; AA: acetic acid; GAE: Gallic acid equivalent; BLQ: Below Limit of Quantification; *BLQ (<0.1) treated with 0.5% bentonite and above only ($p<0.05$). The lightness (L^*) value of the wine increased significantly ($p<0.05$) from 73.06 in control to 76.92 in 1% bentonite treated sample. However, no significant differences were observed in L^* values of samples treated with 0.5% and 1% bentonite ($p>0.05$). It can be seen from Table 1 that the redness-greenness values were positive and between of 4.92 (1% bentonite treated wine sample) and 5.76 (control wine sample), indicating that the samples were slightly red indicating a reduction in wine's greenish hue by about 14.6%. Further, it can been seen that the redness (a^*) values significantly decreased with increasing bentonite concentration ($p<0.05$). The yellowness-blueness values were observed to be positive and in the range of 50.60 and 52.93, indicating that wine samples were yellow. The yellowness values (b^*) slightly (by 3.4%) but significantly decreased ($p<0.05$) when treated with 1% bentonite. The colour intensity of wine samples was also found to significantly decrease from 0.398 in control to 0.310 in 1% bentonite treated samples ($p<0.05$). Cosme et al. (2020) noted that treatment of red wine with 1.2 g/L of bentonite decreased a^* and b^* values while the L^* value increased. Arenas et al. (2021) reported that calcium bentonite increased the L^* value of white wine indicating a lighter colour. Ma et al. (2020) and Cosme et al. (2020) reported that bentonite treatment resulted in a 20% decrease in the colour intensity of Italian Riesling wine and red wine, respectively. In the present study, it can been seen that the total phenols content significantly decreased ($p<0.05$) with the increasing levels of bentonite content (Table 1). The total phenol content was found to decrease from 272.47 mg GAE per litre in control to 135.3 mg GAE per litre in PWAW samples treated with 1% bentonite, registering about 50% reduction. Similar results were reported by Lukić et al. (2023), who noted a decrease of 7% and 3.1% in total phenols and flavonoids, respectively in bentonite-treated wine. Arenas et al. (2021) observed that total phenolic content decreased by about 18.6% and 11.8% with sodium bentonite and calcium bentonite, respectively. Bakardzhiyski (2022) reported that high dosages of bentonite decreased wine phenolics content and reduced its antioxidant activity by about 23%. Bentonite improves the clarity of wine by removing haze proteins and suspended particles, and partial adsorption of pigments such as phenolics and flavonoids. In the present study, the improved clarity of the PWAW samples in terms of increased L^* values, decreased a^*, b^*, and total phenolic content values could be attributed to effective action of bentonite on the suspended particles.

The total soluble solids (TSS) content and the total solids (TS) content of bentonite treated wine samples were found to be significantly reduced compared to the control ($p<0.05$). The TSS content of control wine decreased from 9.07 °Brix to 8.23 °Brix upon treatment with 1% bentonite. While the TS content reduced from 9.29% in control to and 8.70% in samples treated with 1% bentonite. Further, similar observations were made in the total

Table 2: Comparative physico-chemical properties of *paneer* whey-apricot wine with other wines

Parameters	Whey Wine (WW)	Apricot Wine (AW)	*Paneer* Whey-Apricot Wine (PWAW)	Market Apricot Wine (MAW)
Lightness (L^*)	$98.80^{a}\pm0.39$	$78.88^{b}\pm0.04$	$75.89^{c}\pm0.07$	$70.43^{d}\pm0.08$
Redness-Greenness (a^*)	$-0.150^{d}\pm0.06$	$6.39^{a}\pm0.06$	$5.28^{b}\pm0.05$	$4.29^{c}\pm0.04$
Yellowness-Blueness (b^*)	$1.81^{d}\pm0.09$	$58.24^{b}\pm0.05$	$52.38^{c}\pm0.05$	$62.27^{a}\pm0.05$
pH	$4.51^{a}\pm0.006$	$4.51^{a}\pm0.017$	$4.53^{a}\pm0.025$	$3.83^{b}\pm0.015$
Total Soluble Solids (°B)	$8.23^{c}\pm0.115$	$8.97^{a}\pm0.21$	$8.53^{b}\pm0.058$	$7.17^{d}\pm0.06$
Total Solids (%)	$8.59^{c}\pm0.18$	$10.33^{a}\pm0.15$	$8.90^{b}\pm0.047$	$7.94^{d}\pm0.04$
Total sugars (%)	$4.44^{a}\pm0.195$	$4.25^{ab}\pm0.14$	$3.47^{d}\pm0.075$	$4.12^{c}\pm0.021$
Reducing sugars (%)	$3.69^{a}\pm0.13$	$3.71^{a}\pm0.12$	$3.34^{b}\pm0.055$	$3.27^{b}\pm0.021$
Titratable acidity (% M.A.)	$0.432^{c}\pm0.002$	$0.429^{b}\pm0.005$	$0.438^{b}\pm0.007$	$0.557^{a}\pm0.003$
Volatile acidity (% A.A.)	$0.019^{b}\pm0.001$	$0.020^{b}\pm0.001$	$0.020^{b}\pm0.001$	$0.022^{a}\pm0.001$
Ash (%)	$0.305^{d}\pm0.007$	$0.450^{b}\pm0.003$	$0.505^{a}\pm0.005$	$0.333^{c}\pm0.002$
Ethanol (% v/v)	$10.19^{c}\pm0.37$	$12.57^{b}\pm0.36$	$13.19^{a}\pm0.11$	$12.49^{b}\pm0.04$
Methanol (% *v/v*)	*BLQ	*BLQ	*BLQ	*BLQ
Total phenols (mg GAE/ 100ml)	$80.18^{d}\pm6.12$	$163.59^{c}\pm9.42$	$272.47^{a}\pm1.86$	$214.09^{b}\pm1.67$
Total esters (g/L of absolute alcohol)	$61.07^{c}\pm1.73$	$136.49^{a}\pm3.66$	$125.23^{b}\pm4.4$	$124.27^{b}\pm3.22$
DPPH (% inhibition)	$83.18^{b}\pm2.2$	$84.75^{b}\pm0.38$	$91.90^{a}\pm0.071$	$90.34^{a}\pm0.3$
ABTS (% inhibition)	$22.08^{d}\pm0.46$	$77.97^{c}\pm0.63$	$96.00^{a}\pm0.64$	$94.13^{b}\pm0.76$

Mean ± SD (n=3).

^{a,b,c,d} Mean values with different superscript letters within a row differ significantly ($p<0.05$).

MA: Maleic acid; AA: Acetic acid; GAE: Gallic acid equivalent; BLQ: Below limit of quantification; *BLQ (<0.1).

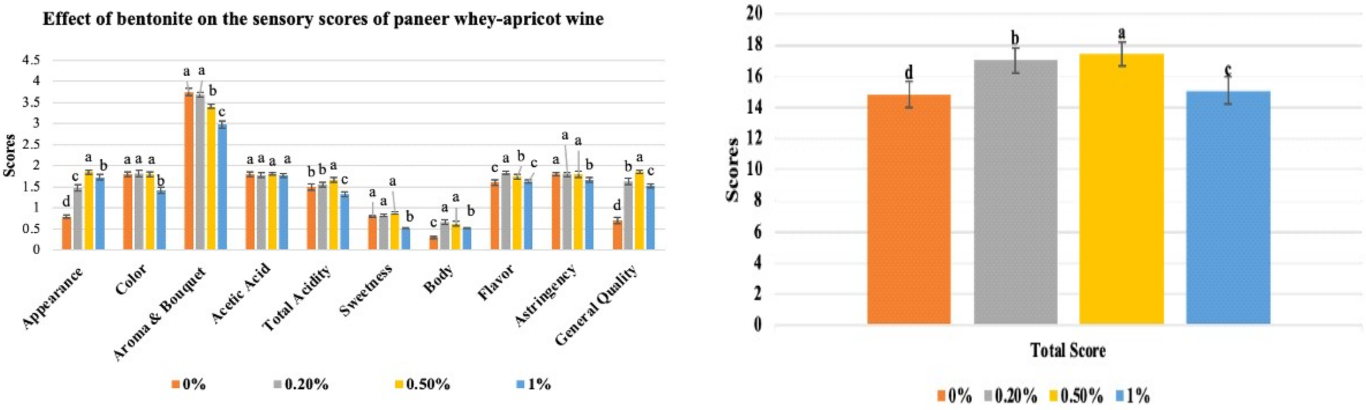

Fig. 1. Effect of bentonite treatment on the sensory scores of paneer whey-apricot wine
Mean ± SD (n=20)
^{a,b,c,d}Mean values with different superscript letters within a sensory attribute differ significantly ($p<0.05$).

sugars and reducing sugars content (Table 1). It can be seen that as the bentonite concentration increased from 0% to 1%, the total sugars and reducing sugars content of wine (PWAW) reduced from 3.85% to 3.44% and 3.71% to 3.29%, respectively. Bentonite primarily targets negatively charged colloids and proteins. In some wines, certain sugars are not present as free monomers (glucose/fructose) but are part of larger, colloidal structures or bound to polysaccharides and glycoproteins. When bentonite adsorbs and removes these colloidal complexes, a portion of the associated sugar moieties can be carried away with the clarifying material. Ma et al. (2020) reported a 10% reduction in total sugar of bentonite-treated wine compared to untreated wine. However, Lukić et al. (2023) observed no change in reducing sugar content of white wine when treated with sodium bentonite (95g/L). In the present study, no significant change was observed in pH, titratable acidity, and volatile acidity of bentonite treated wine samples ($p>0.05$). On the contrary, Dumitriu et al. (2018) reported that sodium bentonite-treated wine resulted in a higher pH due to the change of the tartaric acid equilibrium in the wine. According to Ma et al. (2020) bentonite treatment caused a significant ($p<0.05$) reduction of 2-3% in total acidity and 2-12% in volatile acidity of the wine, which influenced the flavour profile of the wine. Although bentonite has primary effects on protein stability and clarity, it can also have secondary effects on titratable acidity and volatile acidity. It can adsorb organic acids especially the weakly bound ones like tartaric acid or citric acid along with proteins. However, it does not bind volatile acids such as acetic acid. Further, due to the adsorption of amino acids or small peptides (basic compounds) there could be a slight decrease in pH while due to the adsorption of organic acids, there could be a slight increase in the pH. Hence, in the present study, the non-significant changes in the pH, titratable and volatile acidity could be attributed to the modest adsorption of acids by the bentonite.

It can be seen from Table 1 that bentonite treatment led to slight decrease in the ethanol content ($p<0.05$) from 12.91% in control to 12.72% in 1% bentonite treated PWAW samples. However, non-significant ($p>0.05$) effect was observed on the ethanol percentage in the 0.2% and 0.5% bentonite treated wine samples. Ma et al. (2020) reported similar reduction in ethanol content of bentonite treated wine. In the present study, methanol content was observed to be below the limit of detection of the instrument (0.05%) in the wine samples, confirming that prepared wines were safe for human consumption. The total esters content, as presented in Table 1, showed non-significant changes ($p>0.05$) in the treated wine samples when the concentration of bentonite increased from 0.2% to 1%. The ash content of PWAW samples was found to be significantly ($p<0.05$) reduced in the treated wine from 0.547% in control to 0.489% in 1% bentonite treated PWAW samples. On the contrary, Ma et al. (2020) reported a 47.74% reduction in esters in bentonite treated wine compared to control wine while Maslov Bandić et al. (2022) reported that adding bentonite to Sauvignon Blanc wine did not affect the ash content.

Sensory evaluation of the bentonite-treated *paneer* whey-apricot wine

The effect of different levels of bentonite on the sensory evaluation of the *paneer* whey-apricot wine (PWAW) samples is presented in Figure 1(a). The appearance of wine is a very important sensory attribute that gives the first impression of wine quality and affects other sensory qualities (Stefan et al. 2020). The untreated wine (0%) received the lowest appearance score of 0.8 due to its haziness appearance ($p<0.05$). No significant differences in colour scores of the control (0%), 0.2%, and 0.5% treated wines were registered. However, the 1% treated sample received the lowest sensory score (1.42). This was due to a reduction in the color intensity of the wine when higher concentrations of bentonite were used for clarification

(Bakardzhiyski, 2022). The aroma and bouquet scores were significantly high in control (0%) (3.75) and 0.2% treated wines (3.69) ($p<0.05$) which was observed to get decreased to 2.98 as the percentage of bentonite increased to 1%. Bakardzhiyski (2022) reported that the wine aroma decreased with the decreased phenolic content that could be due to the adsorption of phenolic compounds by the bentonite. The high scores achieved among all the wine (PWAW) samples for (absence of) acetic acid ($p>0.05$) suggest that proper hygiene practices were followed throughout the winemaking process, which minimized acetic acid production. This is crucial because it may give a vinegar-like flavor, which is not desirable in good-quality wines. It was also observed that the total acidity increased significantly ($p<0.05$) by about 11.33% when the bentonite concentration rose from 0% to 0.5%. This could be attributed to a decrease in the acid content of wine, which enhanced its sensory acceptability. However, when the concentration increased from 0.5% to 1%, a significant decrease in the total acidity score of wine was observed, which negatively affected its flavor ($p<0.05$). Gutiérrez-Escobar et al. (2021) reported that the fruits' organic acids give a mellow fruit wine flavour.

The sweetness scores of the wine (PWAW) samples revealed no significant ($p<0.05$) change with an increase in the bentonite concentration from 0% to 0.5%. However, there was a significant ($p<0.05$) reduction (by about 41%) in the sweetness scores as the concentration of bentonite increased to 1.0%, which negatively affected the taste profile of the wine, as sweetness is one of the four primary taste profiles (Xynas et al. 2024). The untreated PWAW wine (control, 0%) obtained the lowest scores for mouthfeel compared to treated samples. The PWAW wine flavor scores increased significantly ($p<0.05$) with the increase in bentonite concentration from 0.2% to 1.0%. The astringency score of the wine treated with 1.0% bentonite was found to be significantly low ($p<0.05$) compared to other levels (0%, 0.2, and 0.5%), which may be due to the reduction in the phenolic compounds and tannin content. Xynas et al. (2024) reported that tannins and phenolics contribute to the astringency of the wine. The general quality scores of PWAW wine samples indicated that the samples treated with 0.5% bentonite were deemed good and sensorily acceptable, followed by 0.2%, 1%, and 0%. Additionally, this wine sample achieved significantly ($p<0.05$) higher total score (17.45) compared to other wine samples as shown in Figure 1(b). This showed that the 0.5% treated wine was more sensorily acceptable. Given the non-significant ($p>0.05$) changes in ethanol and light transmittance levels and improved lightness (L^*), reduced redness (a^*) and colour intensity in paneer whey-apricot wine (PWAW) treated with 0.5% bentonite as discussed in the previous section, and the overall higher sensory scores discussed in this section, the paneer whey-apricot wine (PWAW) samples treated with 0.5% bentonite treatment was selected as the optimal concentration and was subsequently used in further experiments.

Comparative physico-chemical properties of paneer whey-apricot wine with other wines

The physico-chemical properties of PWAW, AW, WW and MAW (commercial apricot wine) are presented in Table 2. Significant changes in the lightness (L^*) values of all the wine samples were observed ($p<0.05$). Among all, the L^* value of WW was significantly high (98.8) ($p<0.05$), reflecting its excellent transparency and clarity. While the L^* values of AW, PWAW, and MAW were 78.88, 75.89, and 70.43, respectively. Interestingly, significant differences in the L^* values of the AW (laboratory prepared apricot wine) and MAW (commercially available apricot wine) samples were observed. The value of redness value (a^*) was significantly higher for AW (6.39), followed by PWAW (5.28), and MAW (4.29), and WW (-0.15), which obtained a negative value, indicating very low greenish hue ($p<0.05$). The yellowness (b^*) value was significantly higher in MAW (62.27) than AW (58.24) and PWAW (52.38), which could be attributed due to a higher concentration of apricot fruit used in the preparation of MAW. However, the significantly low b^* values of PWAW as compared to AW ($p<0.05$) could be attributed to the effect of blending of apricot pulp with *paneer* whey. The pH of MAW was found to be significantly low (3.83) ($p<0.05$) compared to WW (4.51), AW (4.51), and PWAW (4.53). The titratable acidity (TA) of AW (0.429%) and PWAW (0.438%) was non-significantly different ($p>0.05$). However, the TA of MAW was significantly high among all the wines (0.557%). Similarly, no significant difference was observed among the volatile acidity of WW, AW, and PWAW ($p>0.05$). However, it was slightly high in market apricot wine sample (MAW) ($p<0.05$). In the present study, all the wine samples recorded lower volatile acidity including the MAW, as good manufacturing practices were followed during the preparation of wines to prevent microbial contamination and met the regulatory standards of volatile acidity of wine, i.e., maximum 1.2 g/L as given by FSS (Alcoholic Beverages) Regulations (2018).

The PWAW exhibited significantly lower TSS (8.53 °B) and TS (8.90 %) values than AW (8.97 °B and 10.33%) but higher values compared to WW (8.23 °B and 8.59 %) and MAW (7.17 °B and 7.94 %) (Table 2). Pu et al. (2023) reported that organic acids increased during the fermentation of small white apricot wine, which resulted in increased acidity, a decrease in pH, and conferred to a sour taste to the wine. The total and reducing sugars content were found to be significantly ($p<0.05$) higher in AW and WW samples than PWAW and MAW. Higher residual sugar content contributes to a sweeter taste in wine, which is desirable to a certain extent; however, beyond that, it adversely affects the sensory properties of wine. In the present study, it was observed that there were no significant differences ($p>0.05$) in reducing sugars contents of PWAW and MAW samples. Further, in the present study, it was observed that the ash content of PWAW was significantly high followed by AW, MAW, and WW ($p<0.05$). The higher ash content in PWAW could be

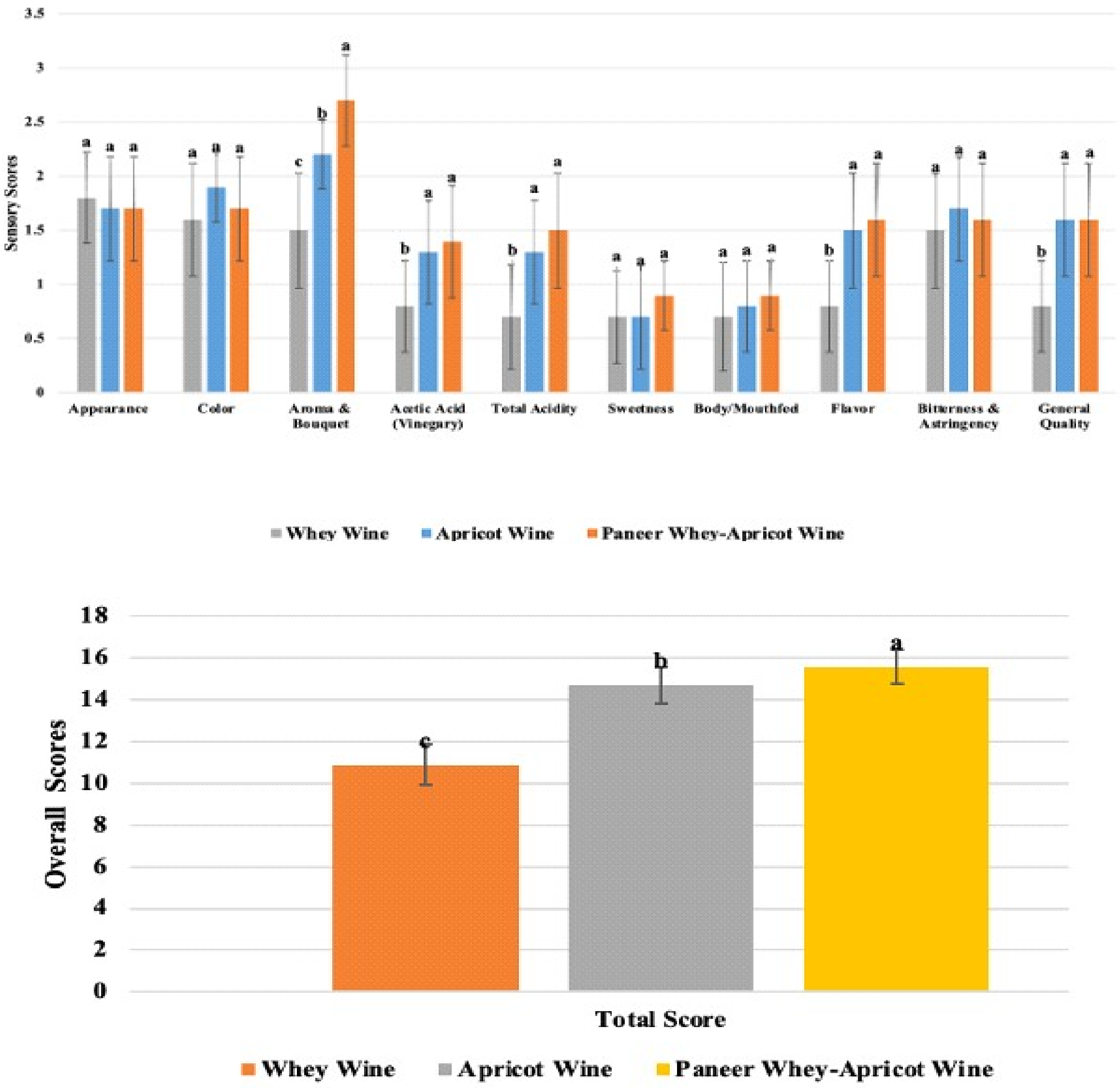

Fig. 2. Comparative sensory scores of *paneer* whey-apricot wine with other wines
Mean ± SD (n=20)
^{a,b,c,d}Mean values with different superscript letters within an attribute differ significantly ($p<0.05$).

attributed to blending of *paneer* whey with apricot pulp for "must" preparation during winemaking. A higher percentage of ash gives a salty taste to the wine, which is not desirable and adversely affects the wine's clarity. Yamahata et al. (2020) reported that demineralized whey produced better alcoholic drinks with higher ethanol content and sensory acceptability as it lacked a milky sensation. In the present investigation, PWAW exhibited significantly ($p<0.05$) higher ethanol content (13.19 %), followed by AW (12.57 %), MAW (12.49 %), and WW (10.19 %). According to the FSSAI's Food Safety and Standard (Alcoholic Beverages) Regulation (2018), the permissible range of ethanol content in fruit wine other than grape wine is between 7.0% and 15.5%, while for the wine prepared from agricultural and plant sources it is 1.5% and 8.0%. Hence, the wines prepared in the present study namely AW, WW and PWAW met the required regulatory standards for ethanol content. Pu et al. (2023) reported that a superior quality wine can be produced from small white apricot with an alcohol content of 11.4% (v/v). Among all the wine samples, methanol content was below the limit of quantification (0.1%) and within the regulatory requirement as the FSSAI's specifications for fruit wine other than grape wine.

The total phenols content of PWAW was found to be the highest (272.47 mg GAE/100 mL) ($p<0.05$), followed by MAW (214.09 mg GAE/100 mL), AW (163.59 mg GAE/100 mL), and WW (80.18 mg GAE/100 mL) (Table 2). This directly contributes to the higher antioxidant capacity of the PWAW, which is manifested in terms of DPPH and ABTS values. Waterhouse and Miao (2021) observed a direct correlation between wine polyphenol content and its antioxidant properties. Sun et al. (2022) studied the fermentation of apricot juice, which enhanced its total phenolic compounds and antioxidant capacity. The total esters enhance the wine flavor, thereby increasing its acceptability among consumers. The total ester content of AW samples was found to be the highest (136.49 g/L) ($p<0.05$), followed by PWAW with 125.23 g/L and MAW with 124.27 g/L, while WW had the lowest content (61.07 g/L).

Comparative sensory evaluation of *paneer* whey-apricot wine with other wines

According to the literature, the best quality wines display high clarity and transparency, with no haziness or suspended particles. They possess a fruity aroma and flavour, derive their colour from fruit pigments, and offer balanced sweetness, body (mouthfeel), as well as lower bitterness and astringency. Sensory qualities vary with evaluators, as there is no standard value for all the above-mentioned parameters. Pu et al. (2023) reported that wine with a good amount of sugar obtained higher scores for mouthfeel and taste and higher consumer acceptability. Zhu et al. (2023) reported that consumers do not like the astringent and bitter taste of fruit wines. With this in background, the individual scores of different sensory attributes obtained during the sensory evaluation of PWAW as compared with WW and AW samples is presented in Figure 2(a) while the overall score is presented in Figure 2(b). The WW samples obtained a mean score of 1.8 (maximum 2.0) for appearance, which is higher due to its clarity and transparency. It lacks any of the visible particles typically found in unclarified fruit wines. The AW was clear, free from haziness and any suspended particles. While the PWAW samples were clear in appearance and obtained statistically similar scores compared to AW and WW. The visual appearances of all three wine samples (AW, WW and PWAW) is presented in Figure 3. The color of WW appeared whitish with a slight greenish tinge and obtained a score of 1.6. In contrast, AW had a yellowish color, while PWAW exhibited a yellowish hue with a very slight green tint due to the presence of *paneer* whey. The obtained results were similar to Pu et al. (2023) who reported a golden color of the small white apricot wine. The WW lacks the aroma and bouquet that was majorly contributed by apricots in both AW and PWAW. Consumer acceptability of fruit wines depends on their taste and aroma (Zhu et al. 2023). The apricot wine (AW) and the *paneer* whey-apricot wine (PWAW) had a pleasing aroma and received significantly higher scores than whey wine (WW) ($p<0.05$) (Figure 2(a)). Pu et al. (2023) reported that there are 23 different esters identified in the wine, which gave aroma to small white apricot wine. WW received a significantly ($p<0.05$) lower total acidity score than PWAW and AW, indicating that it was lacking typical acid taste. No significant differences were recorded in the sweetness, body or mouth feel and bitterness and astringency scores among all the wine samples (PWAW, WW and AW) ($p>0.05$). Pu et al. (2023) reported that wine with a good amount of sugar obtained higher scores for mouthfeel and taste and higher consumer acceptability. Further, it was observed that

Table 2: Comparative physico-chemical properties of *paneer* whey-apricot wine with other wines

Parameters	Whey Wine (WW)	Apricot Wine (AW)	*Paneer* Whey-Apricot Wine (PWAW)	Market Apricot Wine (MAW)
Lightness (*L**)	$98.80^{a}\pm0.39$	$78.88^{b}\pm0.04$	$75.89^{c}\pm0.07$	$70.43^{d}\pm0.08$
Redness-Greenness (*a**)	$-0.150^{d}\pm0.06$	$6.39^{a}\pm0.06$	$5.28^{b}\pm0.05$	$4.29^{c}\pm0.04$
Yellowness-Blueness (*b**)	$1.81^{d}\pm0.09$	$58.24^{b}\pm0.05$	$52.38^{c}\pm0.05$	$62.27^{a}\pm0.05$
pH	$4.51^{a}\pm0.006$	$4.51^{a}\pm0.017$	$4.53^{a}\pm0.025$	$3.83^{b}\pm0.015$
Total Soluble Solids (°B)	$8.23^{c}\pm0.115$	$8.97^{a}\pm0.21$	$8.53^{b}\pm0.058$	$7.17^{d}\pm0.06$
Total Solids (%)	$8.59^{c}\pm0.18$	$10.33^{a}\pm0.15$	$8.90^{b}\pm0.047$	$7.94^{d}\pm0.04$
Total sugars (%)	$4.44^{a}\pm0.195$	$4.25^{ab}\pm0.14$	$3.47^{d}\pm0.075$	$4.12^{c}\pm0.021$
Reducing sugars (%)	$3.69^{a}\pm0.13$	$3.71^{a}\pm0.12$	$3.34^{b}\pm0.055$	$3.27^{b}\pm0.021$
Titratable acidity (% M.A.)	$0.432^{c}\pm0.002$	$0.429^{b}\pm0.005$	$0.438^{b}\pm0.007$	$0.557^{a}\pm0.003$
Volatile acidity (% A.A.)	$0.019^{b}\pm0.001$	$0.020^{b}\pm0.001$	$0.020^{b}\pm0.001$	$0.022^{a}\pm0.001$
Ash (%)	$0.305^{d}\pm0.007$	$0.450^{b}\pm0.003$	$0.505^{a}\pm0.005$	$0.333^{c}\pm0.002$
Ethanol (% v/v)	$10.19^{c}\pm0.37$	$12.57^{b}\pm0.36$	$13.19^{a}\pm0.11$	$12.49^{b}\pm0.04$
Methanol (% *v/v*)	*BLQ	*BLQ	*BLQ	*BLQ
Total phenols (mg GAE/ 100ml)	$80.18^{d}\pm6.12$	$163.59^{c}\pm9.42$	$272.47^{a}\pm1.86$	$214.09^{b}\pm1.67$
Total esters (g/L of absolute alcohol)	$61.07^{c}\pm1.73$	$136.49^{a}\pm3.66$	$125.23^{b}\pm4.4$	$124.27^{b}\pm3.22$
DPPH (% inhibition)	$83.18^{b}\pm2.2$	$84.75^{b}\pm0.38$	$91.90^{a}\pm0.071$	$90.34^{a}\pm0.3$
ABTS (% inhibition)	$22.08^{d}\pm0.46$	$77.97^{c}\pm0.63$	$96.00^{a}\pm0.64$	$94.13^{b}\pm0.76$

^{a,b,c,d} Mean values with different superscript letters within a row differ significantly ($p<0.05$).

MA: Maleic acid; AA: Acetic acid; GAE: Gallic acid equivalent; BLQ: Below limit of quantification; *BLQ (<0.1).

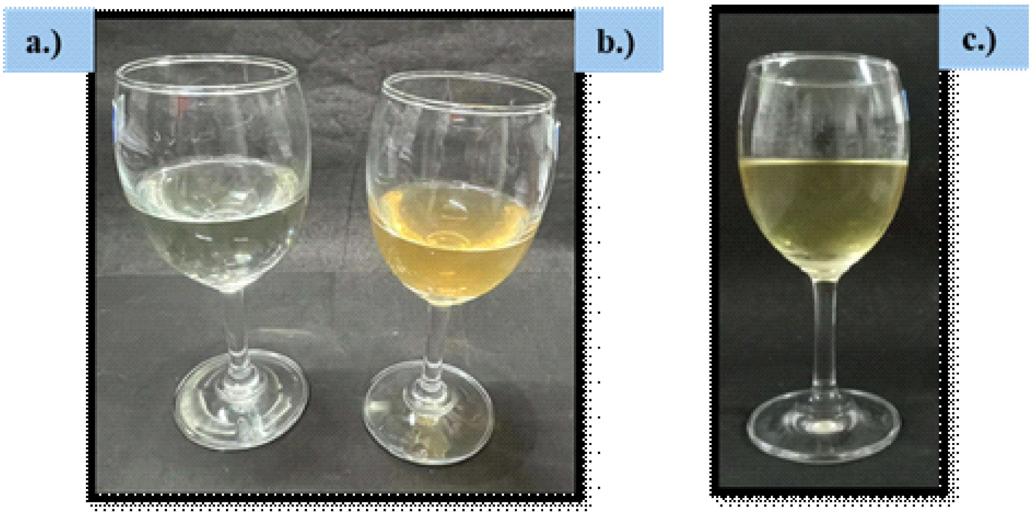

Fig. 3. Visual appearance of freshly prepared wines a.) Whey wine, b.) Apricot wine, and c.) *Paneer* whey-apricot wine

the WW samples were lacking in acceptable flavor and hence, obtained significantly lower scores ($p<0.05$) compared to AW and PWAW, which received better flavour scores due to the presence of apricot pulp solids. Many researchers reported that WW has an unpleasant flavor due to a high ratio of lactose-to-glucose and high acidity, which adversely affect its sensory acceptability (Yamahata et al. 2020). Zhu et al. (2023) observed that taste of fruit wines influences consumer acceptability. To improve the flavor, Gómez et al. (2024) mixed fermented fruit juice with fermented whey, and reported that the resultant product obtained higher sensory scores compared to plain whey wine (WW). In the present study, all the wine samples (WW, PWAW, and AW) had little bitterness and astringency as evidenced from the good sensory scores obtained. The results were in line with findings of Zhu et al. (2023) who reported that consumers do not like the astringent and bitter taste of fruit wines. The general quality scores of PWAW and AW were higher compared to WW, which showed less sensory acceptance. Overall, the PWAW samples obtained higher total scores, which showed the superiority of PWAW in terms of sensory acceptability over the AW and WW.

Effect of aging on different physico-chemical properties of *paneer* whey-apricot wine and other wines

The effect of different levels of bentonite on the physico-chemical properties of *paneer* whey-apricot wine (PWAW) is given in Table 3. It can be seen that the lightness (L^*) value showed a significant ($p<0.05$) improvement among all the wine (PWAW, WW, and AW) samples during aging for a period of 30 days, which could be attributed to settling down of suspended particles in the wine during the prolonged and undisturbed storage. These suspended particles were very fine, which might have not been able to be completely removed during centrifugal separation. It can be seen that the a^* values of WW were observed to be in negative, indicating slightly greenish hue and b^* value to be positive and close to “0”, indicating slight yellow hue, but with no significant changes ($p>0.05$) were observed during aging. While the a^* and b^* values of AW and PWAW were positive and found to be reduced significantly ($p<0.05$) at the end of the aging period. The above results showed that the aging of wine affects the components of wine in different proportions. The TSS content of the aged WW and PWAW wines was observed to significantly decrease ($p<0.05$) but no significant change was observed in AW ($p>0.05$). The TS content and the ash content of all the wine samples (AW, WW and PWAW) was found to significantly ($p<0.05$) decrease upon aging. Mineral ions (e.g., calcium, potassium, magnesium) can precipitate as sparingly soluble salts or complex with organic acids or other molecules, effectively removing them from the soluble phase. Minerals may adsorb proteins, polysaccharides, or other colloids, which may get settled or are removed by fining agents. In the present study, a decrease in the measured value of ash content in the clarified wine could be attributed to the settling of colloids and/or their removal during clarification. The TA of WW and AW was found to decrease ($p<0.05$) up on aging, whereas no notable change in the TA content of PWAW was observed ($p>0.05$). Similarly, no significant changes were observed among the volatile acidities of all aged wines (AW, WW, and PWAW) ($p>0.05$). Abrol *et al.* (2019) reported a reduction in TSS and pH, while total ester and titratable acidity were increased in aged wild apricot vermouth. Organic acids of fruit contribute to the wine TA and give it a mellow taste; however, they are converted into aromatic esters in the aged wines, which improve their sensory quality (Gutiérrez-Escobar et al. 2021). Both total and reducing sugars decreased significantly ($p<0.05$) during aging in WW and AW, while, interestingly, no significant change was observed in PWAW ($p>0.05$). The total esters were found to be higher in the aged AW, followed by aged PWAW and aged WW compared to their corresponding fresh wines (Table 3). Abrol et al. (2019) reported the same findings that total esters in apricot vermouth increased during aging due to the formation of ethyl acetate from the combination of ethyl alcohol and acetic acid. Zhang et al. (2023) findings suggest that both volatile and non-volatile compounds

Table 3: Effect of aging on different physico-chemical properties of *paneer* whey-apricot wine and other wines

Parameters	Whey wine (WW)		Apricot wine (AW)		*Paneer* whey-apricot wine (PWAW)	
	0 day	30 days	0 day	30 days	0 day	30 days
Lightness (*L**)	$98.8^{bA}\pm0.39$	$99.14^{aA}\pm0.32$	$78.88^{bB}\pm0.04$	$80.0^{aB}\pm0.06$	$75.89^{bC}\pm0.07$	$77.01^{aC}\pm0.06$
Redness-Greenness (*a**)	$-0.15^{aA}\pm0.06$	$-0.13^{aA}\pm0.03$	$6.39^{aB}\pm0.06$	$6.3^{bB}\pm0.16$	$5.28^{aC}\pm0.05$	$5.15^{bC}\pm0.02$
Yellowness-Blueness (*b**)	$1.81^{aA}\pm0.09$	$1.70^{aA}\pm0.09$	$58.24^{aB}\pm0.05$	$56.55^{bB}\pm0.05$	$52.38^{aC}\pm0.05$	$52.24^{bC}\pm0.04$
Total soluble solids (ºB)	$8.23^{aA}\pm0.115$	$8.03^{bA}\pm0.12$	$8.97^{aA}\pm0.21$	$8.73^{aB}\pm0.23$	$8.53^{aA}\pm0.06$	$8.17^{bC}\pm0.06$
Total solids (%)	$8.59^{aB}\pm0.18$	$8.36^{bB}\pm0.19$	$10.33^{aA}\pm0.15$	$10.13^{bA}\pm0.11$	$8.9^{aB}\pm0.05$	$8.66^{bB}\pm0.01$
Total sugars (%)	$4.44^{aA}\pm0.195$	$4.21^{bA}\pm0.195$	$4.25^{aAB}\pm0.14$	$4.04^{bA}\pm0.14$	$3.47^{aB}\pm0.075$	$3.43^{aB}\pm0.074$
Reducing sugars (%)	$3.69^{aA}\pm0.13$	$3.4^{bA}\pm0.15$	$3.71^{aA}\pm0.12$	$3.38^{bA}\pm0.12$	$3.34^{aA}\pm0.055$	$3.27^{aA}\pm0.032$
Titratable acidity (%MA)	$0.432^{aA}\pm0.002$	$0.424^{bA}\pm0.002$	$0.429^{aA}\pm0.005$	$0.420^{bA}\pm0.002$	$0.438^{aA}\pm0.007$	$0.427^{aA}\pm0.003$
Volatile acidity (%AA)	$0.019^{aA}\pm0.001$	$0.020^{aA}\pm0.001$	$0.020^{aA}\pm0.001$	$0.021^{aA}\pm0.001$	$0.020^{aA}\pm0.001$	$0.021^{aA}\pm0.002$
Ash (%)	$0.305^{aA}\pm0.007$	$0.288^{bB}\pm0.01$	$0.450^{aB}\pm0.003$	$0.446^{bA}\pm0.006$	$0.505^{aC}\pm0.005$	$0.486^{bA}\pm0.006$
Ethanol (%)	$10.19^{aA}\pm0.37$	$10.03^{aB}\pm0.42$	$12.57^{aB}\pm0.36$	$12.39^{bA}\pm0.36$	$13.20^{aB}\pm0.11$	$12.80^{bA}\pm0.04$
Methanol (%)	*BLQ	*BLQ	*BLQ	*BLQ	*BLQ	*BLQ
Total phenols (mg/L)	$80.18^{aA}\pm6.12$	$75.85^{aA}\pm5.11$	$163.59^{aB}\pm9.42$	$153.26^{aB}\pm9.42$	$272.47^{aC}\pm1.86$	$255.81^{bC}\pm3.37$
DPPH (%inhibition)	$83.18^{aB}\pm2.2$	$82.01^{aA}\pm1.88$	$84.75^{aAB}\pm0.38$	$83.01^{bA}\pm0.66$	$91.90^{aA}\pm0.07$	$90.24^{bB}\pm0.104$
ABTS (%inhibition)	$22.08^{aA}\pm0.46$	$21.80^{aA}\pm0.53$	$77.97^{aB}\pm0.63$	$77.34^{aB}\pm0.71$	$96.00^{aC}\pm0.64$	$95.65^{aC}\pm0.14$
Total esters (g/L of absolute alcohol)	$61.07^{aB}\pm1.73$	$63.48^{aB}\pm0.93$	$132.58^{aA}\pm3.66$	$140.95^{aA}\pm2.06$	$125.25^{aA}\pm4.4$	$129.62^{aA}\pm3.63$

Mean±SD (n=3).

^{a,b} Mean values with different superscript letters in the same row within a wine category differ significantly ($p<0.05$).

^{A,B,C} Mean values with at least one similar superscript in the same row within an aging interval do not differ significantly ($p>0.05$).

MA: Maleic acid; AA: Acetic acid; GAE: Gallic acid equivalent; BLQ: Below limit of quantification; *BLQ (<0.1).

of wine were affected due to various reactions that occur during aging. The total phenols decreased significantly ($p<0.05$) in PWAW after aging, while there was no change observed among the aged WW and AW samples. However, due to a reduction in the wine's phenolic content during aging, a significant reduction in the antioxidant properties in terms of the DPPH activity of AW and PWAW wine samples ($p<0.05$) was observed while no significant changes ($p>0.05$) were observed in terms of ABTS activities of all samples. The obtained results were similar to the findings of Wang et al. (2022), who observed that DPPH and FRAP values of aged red wine decreased. Waterhouse and Miao (2021) reported that antioxidant potential of wine reduces during aging. It can be seen from **Table 3** that the ethanol contents of PWAW and AW significantly reduced ($p<0.05$) from 13.20 to 12.80 and 12.57 to 12.39 %, respectively upon one month of aging, while there was a non-significant change in WW ($p>0.05$). Decreased ethanol content could be attributed to the interaction of alcohols and acids to form esters (Amerine et al. 1980; Zoecklein et al. 1995), which was evident from the increased total esters content during aging. The results obtained were similar to those reported by Abrol et al. (2019), who noted a decrease in the ethanol content of six-month-old wild apricot vermouth. In view of the above results, it is recommended that *paneer* whey-apricot wine (PWAW) may be aged to improve its flavour and clarity.

Conclusion

This study explored the impact of varying bentonite concentrations and aging on the physico-chemical properties and comparative sensory analysis of *paneer* whey-apricot wine (PWAW) with whey wine (WW), apricot wine (AW) and a commercial apricot wine (MAW). It was concluded that bentonite treatment increased the clarity of the PWAW but resulted in significant reduction in total solids, total soluble solids, total and reducing sugar, and total phenolic content. Hence, based on the light transmittance, ethanol content, and total sensory scores, 0.5% of bentonite treatment was selected and considered as optimum. The optimally bentonite treated wine had acceptable physico-chemical and sensory properties and had a higher amount of ethanol and antioxidant properties compared to WW, AW, and MAW. Statistically, no significant differences were found in most of the quality attributes of PWAW wine up on one-month aging compared to freshly prepared PWAW wine. It can be concluded that optimally bentonite treated paneer whey-apricot wine (PWAW) contained good amount of total phenolic content, which contributed to significantly high DPPH and ABTS activities. The study revealed the potential of using *paneer* whey, a major dairy byproduct, and Ladakhi apricot pulp with optimum quality for helping the dairy industry to meet the goals of circular economy and sustainability.

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