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ORIGINAL ARTICLE

Enhancing the Lipid Profile of Heavy Whipping Cream through Fortification with Pecan Nut and Almond Powder: A Chemical Characteristics Study

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KEYWORDS

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ABSTRACT

Heavy Whipping Cream (HWC) is rich in saturated fats, but excessive consumption may pose cardiovascular risks. This study explores fortifying HWC with antioxidant-packed pecan and almond powders to improve its lipid composition. We enriched HWC with 10%, 20%, and 30% of these powders and stored the blends for 90 days. Acid and peroxide values were monitored every 30 days. Throughout storage, all variants exhibited increased acid values. Notably, the 30% pecan powder variant reached a 2.26% oleic acid level by day 90, significantly surpassing the control's 0.43% ($p<0.01$). Conversely, peroxide values were lower in nut-enhanced HWC, with the 30% almond powder variant showing 0.41 on day 90 compared to the control's 0.87 ($p<0.01$). Stability duration decreased with higher powder concentrations, declining from 3.4 hours in the control HWC to 1.9 hours in the 30% almond blend. Fortifying HWC with pecan and almond powders can boost its nutritional content by introducing unsaturated fats, phytosterols, polyphenols, and antioxidants. However, this fortification accelerates hydrolytic rancidity due to increased unsaturated lipid levels, although it likely delays oxidation through antioxidant properties. Results indicate that nut powder levels between 10-20% strike a balance between nutritional enhancements and minimal impact on chemical stability. Pecan and almond powders can effectively elevate the nutritional profile of HWC without significantly affecting its storage characteristics.

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Introduction

Heavy Whipping Cream (HWC), a dairy product, is known for adding a rich, creamy texture to dishes and supplying essential nutrients like calcium, vitamin A, and vitamin D. When consumed in moderation, HWC can be a source of healthy fats, vitamins, and minerals, contributing to a balanced diet. Moderate consumption has been noted for providing prolonged satiety, potentially enhancing dietary satisfaction (Mehta and Pinto, 2023). However, HWC is high in calories and saturated fat. A single tablespoon contains approximately 52 calories and 3.5 g of total fat, with about 2.4 g being saturated fat (Kavindi *et al*., 2021). The intake of saturated fats is linked to increased levels of low-density lipoproteins (LDL), or 'bad' cholesterol, elevating the risk of heart disease (Nergiz-Unal *et al*., 2020; Maki *et al*., 2021; Wang *et al*., 2022). HWC may not be suitable for individuals with lactose intolerance or dairy allergies, as its lactose content can lead to digestive issues (Sekar *et al*., 2020). Excessive consumption can also contribute to weight gain due to its high calorie count, potentially exacerbating cardiovascular health risks (Legassa, 2020).

While HWC offers valuable nutrients, its high saturated fat and cholesterol levels call for optimization to better support cardiovascular health (Selby *et al*., 2019; Bodell *et al*., 2023). Modifying its lipid profile could mitigate potential negative impacts without sacrificing its organoleptic properties. Precisely altering fatty acid composition and quantifying sterols could improve the risk-benefit ratio, positively affecting cardiovascular indicators commonly associated with numerous diseases (Skulas-Ray *et al*., 2019). Maintaining sensory qualities akin to traditional HWC would support its continued popularity and consumption patterns.

Current research shows that the kernel is rich in nutrients, primarily deriving energy from its significant fat reserves (Godfrey *et al*., 2012; Cunnane and Crawford, 2014; Tanprasertsuk *et al*., 2021). Quantitative studies reveal that over three-quarters of the total fatty acids in kernels are unsaturated (Koletzko *et al*., 2019). Among these, monounsaturated fats like oleic acid are prominent, known for reducing LDL cholesterol levels without adversely affecting HDL cholesterol, thereby decreasing cardiovascular disease risk (Liu *et al*., 2023; Roozban *et al.*, 2006). Besides unsaturated fats, kernels contain substantial phytosterols—plant sterols similar to cholesterol (Olatunya *et al*., 2019). These phytosterols may reduce blood cholesterol by inhibiting its intestinal absorption. Kernels also contain tocopherols and squalene, a triterpene involved in cholesterol synthesis (Poli *et al*., 2021). These compounds, along with the kernel’s unsaturated fats, may jointly protect cardiovascular health through their antioxidant, anti-inflammatory, and lipid-regulating properties (Jahanbabi *et al.*, 2021; Wang *et al*., 2021).

Further research confirms that pecan nuts (*Carya illinoinensis*) are rich in polyunsaturated ω_3 and ω_6 fatty acids (Siebeneichler *et al*., 2023). Analyses show that up to 70% of pecan fatty acids are linoleic acid, indicating that pecans are a dense source of this fatty acid. The study of pecan fatty acids and their bioavailability may reveal their nutritional and health benefits. Pecans also contain significant tocopherols, predominantly γ-tocopherol (Curiel-Maciel *et al*., 2021; Ajam Gard, 2022), and have been found to contain 115.59 mg per 100 g of various phytosterols (Descalzo *et al*., 2022). Key phytosterols in pecan nuts include β-sitosterol, Δ5-avenasterol, and campesterol (Bouali *et al*., 2014). These sterols may lower blood lipid levels and reduce cardiometabolic disease risk by inhibiting cholesterol absorption (Jessup *et al*., 2008; Jahanbani *et al.*, 2018; Nattagh-Eshtivani *et al*., 2022). Additionally, phytosterols may reduce certain cancer risks and enhance immune function through their anti-inflammatory and pro-apoptotic effects (Shahzad *et al*., 2017; Pham *et al.*, 2020). Pecan nuts have also been shown to contain a substantial amount of polyphenols, with 1570 gallic acid equivalents (GAE) per 100 g (Ortiz Quezada, 2010). These polyphenols provide significant oxidative protection, particularly by inhibiting the oxidation of low-density lipoprotein, a critical process in atherogenesis. Pecans also have notable amounts of squalane, a triterpene known to neutralize reactive oxygen species, thereby protecting lipids and other macromolecules from oxidation (Iqbal *et al*., 2023; Habibi et al., 2023). Collectively, the rich phenolic content and presence of squalane in pecan nuts support their potential cardiovascular benefits and other health advantages associated with reduced oxidative stress.

Prunus dulcis, commonly known as almonds, like other nuts and oilseeds possess a significant monounsaturated fatty acid (MUFA) profile (Ghezel *et al*., 2022; Sarikhani *et al*., 2021). Quantitative analysis reveals that about 80% of the total fatty acids in almonds are oleic acid (Ghezel *et al*., 2022; Ossama *et al*., 2021), positioning them as a beneficial dietary component. Additionally, almonds contain substantial amounts of phytosterols, ranging from 115-128 mg per 100 g (Özcan, 2023). Profiles of various almond varieties show that β-sitosterol constitutes approximately 80% of their total sterol content. As the predominant phytosterol, β-sitosterol is likely a key contributor to almonds' health benefits, particularly through its role in competitively inhibiting intestinal cholesterol absorption (Roncero *et al*., 2020). Furthermore, almond oil has been found to have the highest vitamin E content among nuts, at 48.12 mg per 100 g (Özdemir *et al*., 2016), highlighting its strong antioxidative properties. Almonds are also notable for their high squalane levels—measured at 193.8 µg g^{-1}—adding to their protective capabilities against oxidation through radical scavenging activity (Fernandes *et al*., 2017; Khojand *et al*., 2023). Overall, the combination of almonds' phytosterol content, high vitamin E, and significant squalene levels endow them with comprehensive defenses against cardiovascular disease and other chronic illnesses related to oxidative stress.

The primary objective of this study is to examine the effects of supplementing HWC with pecan nut and almond powders on its chemical properties during refrigerated storage. This research aims to understand how adding pecan and almond powders affects the acid value, peroxide value, and oxidation stability of HWC. The study methodically assesses the alterations in these chemical parameters in HWC enriched with various concentrations of pecan and almond powders over a 90-day refrigerated storage period. The goal is to determine the impact of these nut powders on the chemical profile of HWC, with a specific focus on lipid oxidation and overall chemical stability. By analyzing these chemical changes, the study contributes valuable insights into the formulation and storage characteristics of HWC when modified with these nut powders, while not addressing any health-related aspects or implications.

Material and Methods

HWC, along with fresh and quality pecans and almonds, were sourced from a local market. Hexane, ethanol, sodium thiosulfate, potassium iodide, and chloroform were obtained from Sigma-Aldrich (USA), and acetic acid was procured from Shanghai Aladdin Biological Technology Co., Ltd. All chemicals and solvents used in this study were of analytical grade. The kernels of pecans and almonds were cleaned, and then ground using a hammer mill model 141 into a fine powder (200-mesh size). This powder was subsequently blended into pre-prepared HWC at concentrations of 10%, 20%, and 30%. The mixtures were thoroughly stirred for 15 minutes at 25°C to ensure uniform consistency. The samples were then meticulously sealed, some using vacuum sealing in food-grade polyethylene terephthalate (PET) containers, while others were sealed conventionally in the same type of containers. They were then refrigerated at 3°C, a temperature chosen based on the study by Raisi *et al*. (2015), for subsequent analysis. Acid and peroxide values were measured according to protocols established by the

American Oil Chemists' Society (AOCS) and the Association of Official Analytical Chemists (AOAC) (Nina *et al*., 2020). Initially, 5 g of the enriched HWC sample was dissolved in 40 ml of hexane. The solution was stirred for 30 minutes on a magnetic stirrer, and then filtered using a Buchner funnel, with the residue washed twice with 20 ml of hexane. The hexane was evaporated using a rotary evaporator under vacuum at 40°C. To the resulting oil, 30 ml of an acetic acid-chloroform solution (2:3 v/v) was added. Then, 0.5 ml of saturated potassium iodide solution was introduced, and the mixture was left in the dark for one minute. Next, 30 ml of distilled water and 0.5 ml of 1% starch reagent were added, and the solution was titrated with 0.01N sodium thiosulfate until the blue color vanished, enabling peroxide value calculation. Acid and peroxide values were assessed every 30 days over a 90-day storage period, and oxidative stability was evaluated on the first day of production.

In this study, data were rigorously analyzed using a factorial framework within a completely randomized design, processed through SAS software. The Analysis of Variance (ANOVA) method examined the effects of three main factors: treatment, storage duration, and packaging. The treatment levels included the control group (untreated HWC) and HWC enriched with varying concentrations of pecan and almond powders, specifically at 10%, 20%, and 30% for both nuts. Storage duration was divided into four periods: 1, 30, 60, and 90 days, to observe changes in HWC's chemical properties over time. Packaging methods were divided into standard and vacuum-sealed options to assess their impact on product quality. Tukey's post-hoc test was used for mean comparisons between groups, with a significance threshold of $p<0.05$. This factorial design allowed for a comprehensive analysis of each factor's individual and combined effects on the HWC's chemical characteristics. Comparisons were made between the control group and the various nut-enriched treatments across different storage times and packaging methods. This approach provided an efficient and thorough examination of multiple variables and their potential interactions.

Results

The outcomes of the ANOVA regarding the chemical properties of HWC are detailed in Table 1. Table 2 presents a comparative analysis of the mean values for the acid value. Our findings indicate that the acid value was significantly higher ($p<0.01$) in HWC samples containing kernel powders compared to the control group. Additionally, a positive correlation was observed in the kernel-enriched HWC, where the acid values increased proportionally with higher kernel content. Over time, an upward trend ($p<0.05$) in acid value was noted. Moreover, samples stored under vacuum conditions exhibited significantly ($p<0.01$) lower acid values compared to those in standard packaging.

Regarding oxidative stability, Table 2 also provides insights into the peroxide values across different sample types. The results showed that HWC samples with kernel powders had significantly lower peroxide values ($p<0.01$) than the control. During storage, both the kernel-enhanced HWC and control samples experienced an increase in peroxide value over time ($p<0.01$). However, the rate of this increase differed between the control and kernel-containing samples, becoming more pronounced in the latter after 30 days. Kernel-enriched samples stored under vacuum conditions exhibited no significant change in peroxide value in the initial 30 days, but a noticeable increase was observed thereafter. Vacuum-stored samples consistently showed significantly lower peroxide values ($p<0.01$) throughout the study compared to those in conventional packaging.

Table 3 highlights the stability duration of HWC supplemented with pecan and almond kernel powders. The results indicated that adding these kernel powders significantly reduced the induction time at 100°C ($p<0.01$) compared to the control HWC. A higher proportion of kernel powders was associated with a shorter induction time, suggesting reduced oxidative stability in HWC with increased kernel content.

Table 1. ANOVA of chemical characteristics of HWC.

Source of variation	degrees of freedom (DF)	sum of squares (SS)		p-value
Treatment	6	1.530	0.478	< 0.01
Storage time	3	5.548	0.532	< 0.01
Packaging	1	0.675	0.088	< 0.01
Treatment × Storage time	18	0.238	0.013	< 0.01
Treatment × Packaging	6	0.105	0.002	< 0.01
Treatment × Storage time × Packaging	18	0.026	0.001	< 0.01

Table 2. Comparative analysis of mean acid value and peroxide value across HWC types, storage durations, and packaging methods.

Time (days)				1	30	60	90
Acid value (as percentage of oleic acid), CV=2.98%							
Treatment	Control group		Vacuum	0.27±0.009d	0.29±0.008e	0.32±0.005f	0.38±0.011c
			Conventional	0.27±0.009d	0.36±0.009d	0.38±0.012g	0.43±0.000c
	HWC + almond powder	10%	Vacuum	0.32±0.009cd	0.60±0.003d	0.82±0.064e	1.03±0.008d
			Conventional	0.32±0.009cd	0.63±0.018c	0.85±0.012f	1.12±0.008d
		20%	Vacuum	0.36±0.009bcd	0.86±0.028b	1.08±0.018d	1.37±0.009c
			Conventional	0.36±0.009bcd	0.93±0.000b	1.14±0.060e	1.40±0.014c
		30%	Vacuum	0.42±0.013ab	0.95±0.006ab	1.22±0.037c	1.43±0.004c
			Conventional	0.42±0.013ab	0.98±0.002ab	1.25±0.030d	1.47±0.000c
	HWC + pecan nut	10%	Vacuum	0.40±0.018abc	0.61±0.045cd	1.31±0.045be	1.67±0.017b
			Conventional	0.40±0.018abc	0.93±0.003b	1.79±0.082c	2.00±0.037b
		20%	Vacuum	0.46±0.009ab	0.71±0.013c	1.40±0.021ab	1.81±0.026a
			Conventional	0.46±0.009ab	0.94±0.047b	1.92±0.000b	2.11±0.043b
		30%	Vacuum	0.48±0.005a	1.05±0.005a	1.46±0.059a	1.88±0.014a
			Conventional	0.48±0.005a	1.08±0.005a	2.09±0.276a	2.26±0.025b
Peroxide value, CV=4.57%							
Treatment	Control group		Vacuum	0.33±0.018a	0.64±0.024a	0.71±0.044a	0.77±0.029a
			Conventional	0.33±0.018a	0.73±0.015a	0.86±0.021a	0.87±0.029a
	HWC + almond powder	10%	Vacuum	0.08±0.004b	0.09±0.007b	0.15±0.003e	0.27±0.009d
			Conventional	0.08±0.004b	0.12±0.010e	0.19±0.008e	0.30±0.002f
		20%	Vacuum	0.10±0.002b	0.10±0.002b	0.20±0.019de	0.30±0.016d
			Conventional	0.10±0.002b	0.17±0.008de	0.29±0.012d	0.35±0.002ef
		30%	Vacuum	0.10±0.002b	0.11±0.004b	0.31±0.019b	0.41±0.023b
			Conventional	0.10±0.002b	0.25±0.007bc	0.36±0.017c	0.41±0.023b
	HWC + pecan nut	10%	Vacuum	0.10±0.007b	0.10±0.007b	0.23±0.007cd	0.32±0.006cd
			Conventional	0.10±0.007b	0.12±0.004e	0.25±0.020de	0.37±0.005de
		20%	Vacuum	0.10±0.002b	0.10±0.001b	0.29±0.004bc	0.36±0.002bc
			Conventional	0.10±0.002b	0.19±0.105cd	0.34±0.009c	0.43±0.004cd
		30%	Vacuum	0.11±0.002b	0.12±0.001b	0.33±0.016b	0.42±0.009b
			Conventional	0.11±0.002b	0.30±0.008b	0.42±0.003b	0.51±0.021b

Note: Differing letters are utilized to signify the statistical significance of treatment comparisons

Table 3. Stability time of different HWC treatments

Ingredient	Percentage	Stability Duration (Hour)
Almond powder	10%	2.9
	20%	2.4
	30%	1.9
Pecan nut	10%	3.1
	20%	2.5
	30%	2.1
Control	-	3.4

Discussion

This study provides valuable insights into the effects of enriching HWC with pecan nut and almond powders on selected chemical properties during refrigerated storage. The increase in acid value observed in HWC with added kernels aligns with similar studies on plant-based lipids in dairy products (Leahu *et al*., 2022; Puşcaş *et al*., 2022). This rise can be attributed to hydrolytic rancidity caused by the enzymatic activity of lipase found in the pecan and almond powders (Ghavami, 2022). Lipases, which are active in water activity levels as low as 0.2 or 0.5, interact with the HWC's water content, around 16%, to release butyric acid, leading to a noticeable rancid flavor (Fernandes *et al*., 2017; Liu *et al*., 2023).

The higher unsaturated fatty acid content from the nut powders likely speeds up this process through enzymatic and possibly non-enzymatic mechanisms, resulting in the liberation of free fatty acids and an increase in acid value (Raisi *et al*., 2015; Kavindi *et al*., 2021). Vacuum packaging's effectiveness in mitigating this effect is probably due to reduced oxygen exposure, thus limiting oxidative reactions that can promote further hydrolysis. This trend is consistent with Raisi *et al*. (2015), who observed increased acidity in almond-enriched ice cream over time.

Moreover, the significantly lower peroxide value in enriched HWC may be due to the addition of antioxidant components like tocopherols, phytosterols, phenolic compounds, and squalene from the pecan and almond kernels. This observation aligns with findings of lower peroxide values in HWC with added nut powders compared to plain HWC, suggesting these bioactive compounds offer some protection against lipid oxidation (Nina *et al*., 2020; Khojand *et al*., 2023). However, the gradual increase in peroxide value over time indicates that these antioxidants delay rather than completely prevent oxidation.

The decrease in oxidative stability with higher proportions of pecan and almond powders is associated with the increased presence of polyunsaturated and monounsaturated fatty acids (PUFA and MUFA). The dominance of PUFA in pecan nuts and MUFA in almonds results in shorter induction times, reflecting reduced stability due to higher oxidation susceptibility compared to the saturated fats in plain HWC (Ossama *et al*., 2021; Özcan, 2023). Furthermore, the rise in peroxide value over time in these samples could be attributed to autocatalytic lipid oxidation reactions. Additionally, the greater peroxide value in conventionally packaged products may result from extended oxygen exposure compared to vacuum-sealed counterparts (Nergiz-Unal *et al*., 2020; Skulas-Ray *et al*., 2019).

In summary, fortifying HWC with pecan and almond powders enhances storage stability and antioxidant protection but also increases vulnerability to hydrolytic rancidity. Lower percentages of nut powders (10-20%) seem to offer a better balance between nutritional improvement and storage stability. Future research should explore supplementing these nut enrichments with additional antioxidants and antimicrobials to further enhance stability and extend shelf life. Assessing the sensory qualities and consumer acceptance of such enriched HWC products would also be a valuable extension of this research.

Conclusions

This study offers new insights into the chemical impact of enriching HWC with pecan and almond nut powders. Adding 10-30% of pecan and almond kernels to HWC significantly affected its acid value, peroxide value, and oxidative stability over 90 days of refrigerated storage. The increase in acid values at higher nut powder concentrations suggests enhanced hydrolytic rancidity, likely due to increased unsaturated fatty acid content. Conversely, the decrease in peroxide values indicates that the antioxidants, phytosterols, and polyphenols in the nuts helped to delay lipid oxidation. The analysis of chemical attributes reveals that fortifying HWC with pecan and almond powders boosts its nutritional value but also presents some storage challenges. The nuts contribute beneficial unsaturated lipids, phytosterols, and polyphenols, enhancing health benefits. However, the elevated unsaturated fat levels may promote hydrolytic rancidity while simultaneously delaying oxidation through antioxidant actions. The findings suggest that using lower nut powder levels, approximately 10-20%, optimally balances nutritional enhancement with minimal impact on stability. Vacuum packaging also emerged as a promising method for improving storage properties. Future research should expand on these results by assessing the sensory qualities of nut-enriched HWC and exploring the addition of supplemental antioxidants and antimicrobials.

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Conflict of Interest

The authors declare no conflict of interest.

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