Indo. J. Chem. Sci. 15 (3) (2026)
Indonesian Journal of Chemical Science
http://journal.unnes.ac.id/sju/index.php/ijcs

Effects of the Packaging Material and Storage Time on the Controlled Release of the Volatile Compounds in Lemongrass and Cinnamon in Cinnamal Tea Bags

Bella Permatasari ✉, Adrian Maulana Zaky, Sabila Aisyah, Tri Handayani, and Edy Cahyono

Chemistry Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, D6 Building, Sekaran Campus, Gunungpati, Semarang, Central Java, 50229, Indonesia

Article Info

Accepted: 28-06-2025

Approved: 16-07-2026

Published: 13-11-2026

Keywords:
Packaging material
Storage time
Controlled release
Volatile compounds
Cinnamal tea

Abstract

The purpose of this study is to **analyze** the effectiveness of packaging material types and storage time on the controlled release of volatile compound components in cinnamal tea bag products. Analysis of the concentration of volatile compounds during the storage period was carried out using GC (gas chromatography) and GC-MS (gas chromatography-mass spectrometry). The decrease in volatile compounds can be determined by comparing the percentage of area for each variation in storage time and type of dipping bag material, because the peak area is proportional to the level of sample components. The results showed that the controlled release ability of volatile compounds varied depending on the tea matrix. In black cinnamal tea, PLA (polylactic acid) packaging was superior, maintaining a larger and more stable concentration of compounds during storage. Conversely, in green cinnamal tea, NWP (natural wood pulp) packaging demonstrated superior performance, showing a more stable concentration pattern after 5 days and higher concentration values at the end of the 30-day storage period. This difference suggests that the interaction between the tea matrix (oxidized black tea vs. unoxidized green tea) and the packaging material's barrier properties plays a crucial role in volatile compound retention.

Abstrak

Tujuan penelitian ini adalah menganalisis pengaruh jenis bahan kemasan dan lama penyimpanan terhadap pelepasan terkendali komponen senyawa volatil dalam produk teh cinnamal kemasan kantong. Analisis konsentrasi senyawa volatil selama masa penyimpanan dilakukan dengan menggunakan GC (kromatografi gas) dan GC-MS (kromatografi gas-spektrometri massa). Penurunan kadar senyawa volatil dapat ditentukan dengan membandingkan persentase luas puncak untuk setiap variasi waktu penyimpanan dan jenis bahan kantong perendaman, karena luas puncak berbanding lurus dengan kadar komponen sampel. Hasil penelitian menunjukkan bahwa kemampuan pelepasan terkendali senyawa volatil bervariasi tergantung pada matriks tehnya. Pada teh cinnamal hitam, kemasan PLA (asam polilaktat) menunjukkan kinerja yang lebih unggul, dengan mempertahankan konsentrasi senyawa yang lebih tinggi dan lebih stabil selama penyimpanan. Sebaliknya, pada teh cinnamal hijau, kemasan NWP (pulp kayu alami) menunjukkan kinerja yang lebih unggul, dengan pola konsentrasi yang lebih stabil setelah 5 hari dan nilai konsentrasi yang lebih tinggi pada akhir periode penyimpanan 30 hari. Perbedaan ini menunjukkan bahwa interaksi antara matriks teh (teh hitam teroksidasi vs. teh hijau tidak teroksidasi) dan sifat penghalang bahan kemasan memainkan peran penting dalam retensi senyawa volatil.

© 2026 Universitas Negeri Semarang

✉ Correspondence address:
Building D6 Floor 2, Sekaran Campus, Gunungpati, Semarang 50229
E-mail: bellaper35@students.unnes.ac.id

p-ISSN 2252-6951
e-ISSN 2502-6844

Introduction

Recently, Cahyono, *et al.* (2021) have developed a formulation of green tea and black tea with the addition of cinnamon powder spices as a source of cinamaldehyde compounds and lemongrass essential oil vapor as a source of citral compounds using a stirred boiler tank. The mixing of tea with spices aims to add taste, aroma, and cytotoxic properties, especially as a chemo-preventive tea drink. Cinnamaldehyde and citral are essential oil components of the cinnamon and lemongrass plants that belong to aldehyde compounds. Compounds that have an aldehyde group are essential oil components that have activity as cytotoxic compounds (Xiao *et al*., 2014).

Essential oils are complex biosynthetic compound liquids characterized by a strong aroma (Tian *et al*., 2021). Essential oils are made up of volatile compounds that are unstable and susceptible to damage from exposure to oxygen, light, moisture, and heat. These changes have a negative effect on the quality of products containing essential oils, such as causing unpleasant tastes that can damage sensory properties or produce free radicals that impair stability (Ammari & Schroen 2018).

The release rate of some active substances over time can be regulated through several technologies so that the concentration of active substances on the surface of food can be maintained, thereby extending the shelf life and maintaining its efficacy. The selection of appropriate packaging materials or physical designs can control the rate of release of active substances in food ingredients for a much longer period of time. Thus, the selection of packaging materials as a barrier to the loss of volatile compounds in food is an important characteristic.

An important requirement in choosing a food packaging system is the barrier properties of the packaging material. Barrier properties include gas permeability (such as O_2, CO_2, and N_2), water vapor, aroma compounds and light (González-López *et al*., 2023). This is an important factor in maintaining the quality of packaged food. Food packaging provides varying levels of protection, depending on the properties of the polymer and the structure created by the polymer combination (Vallejos *et al*., 2022). Minimizing the air encountering the product is the best solution to preserve the aroma of the product.

The volatile compound in packaged cinnamal tea product can decrease during distribution, which allows the shelf life of the product and its pharmacological properties to be reduced. Therefore, the effect of using different types of packaging during storage time on the content of volatile compounds needs to be investigated to obtain good packaging materials for maintaining the content of volatile compounds in cinnamal tea bag products

Method

The instrument used in this study are a set of glassware, separation funnels, clamps, and statifs, plastic boxes, digital scales (Ohaus), sealer hands machine (Matrix), stirred boiler tanks, gas chromatography (Agilent 6820 Version A.01 03), GC-MS (Shimadzu GCMS-2010 Plus), and a magnetite stirrer (Dlab MS7-H550-Pro). Meanwhile, the ingredients used in this study are black tea and green tea obtained from brand Pasir Walik Sleman Yogyakarta, lemongrass essential oil obtained from distillation at Rumah Atsiri Tawangmangu, Central Java, cinnamon powder obtained from the market in Semarang, Central Java, n-heksan (85%, Merck), and tea bags made of nylon, PLA, and NWP purchased on trusted online shopping sites.

The preparation of black/green cinnamal tea begins with the mixing of the ingredients in the stirred boiler tank, a 200 ml of lemongrass essential oil is put into the boiler tank, then 500 grams of green tea/black tea and 10 grams of cinnamon powder are put into the tank mixer. Stir the green/black tea mixture and cinnamon powder in the tank mixer at 20 rpm for 15 minutes. Then, heat the essential oil in the boiler tank to a temperature of 70℃ and the pressure is maintained to 1.5 bar. After heating is complete, run the essential oil vapor for 10 seconds through the pipe to the mixer tank while the tea in the mixer tank is stirred for 15 minutes. Store the resulting tea in an airtight container (Cahyono *et al*., 2021).

Tea packaging is done manually by filling tea bags with 2 grams of cinnamal green or black tea and pressing using a selear hand machine. Then, each type of tea bag material that has been filled with the cinnamal tea is put in a plastic box and placed at room temperature so that the storage temperature is relatively controlled. The durability of the essentials oil compound in the tea mixture is tested by controlling their release by making tea extract. Each tea bag is extracted with 200 mL of boiling water. Extraction was carried out in a closed schott durran bottle for 30 minutes, with 5 minutes of stirring at the beginning using a magnetic stirrer at a speed of 570 rpm. After that, extraction with n-hexane of as much as 10 mL was carried out using a separate funnel. The obtained n-hexan extract is evaporated to a volume of 0.1 mL. Next, the

extract was analyzed with GC and MS. This test was carried out at the storage time of 0, 5, 10, 15, 20, 25, and 30 days of tea bags on black cinnamal tea and green cinnamal tea

Results and Discussion

Cinnamal Tea Production

Mixing tea with cinnamon powder and lemongrass essential oil is carried out using a stirred boiler tank. The boiler functions to convert essential oils into steam at high temperatures and pressures. Lemongrass essential oil is heated at a temperature of 70°C to a pressure of 1.5 bar. The mixing of tea and cinnamon powder is carried out in a tank with a stirrer in it with a stirring speed of 20 rpm, and then the mixture of tea and cinnamon is steamed with essential oils through a pipe that connects the two tanks.

Mixing tea with cinnamon powder in a mixer tank is done physically without heating, making mixing less effective. Cinnamon powder is likely still left on the tank walls and affects the quantity of cinnamon powder in the final formulation of cinnamal tea. In addition, the factor of inhomogeneous mixing can occur due to the difference in size between two particles (Shenoy *et al.*, 2015). The size of tea and cinnamon powder was different. So, only few powders can mix with the lemongrass oil, allowing only the top mixture to be impregnated with lemongrass oil.

The result of mixing cinnamon powder and lemongrass essential oil vapor in black tea and green tea changes the color of both to become more yellowish. The yellowish color is caused by mixing tea with cinnamon powder, which has a yellowish-brown color, and adding the hot steam of lemongrass essential oil, which has a bright yellow color. In addition, the cinnamon flavor and smell of lemongrass oil enrich the aroma of tea organoleptically. The difference in tea color is shown in Figure 1.



Figure 1. (a) Green tea, (b) green cinnamal tea, (c) black tea, and (d) black cinnamal tea

Cinnamal Tea Packaging

The packaging of black cinnamal tea and green cinnamal tea is carried out with tea bags made of nylon, PLA, and NWP. Nylon tea bags have an irregular weave structure, while PLA and NWP have irregular weave structures, as shown in Figure 2.

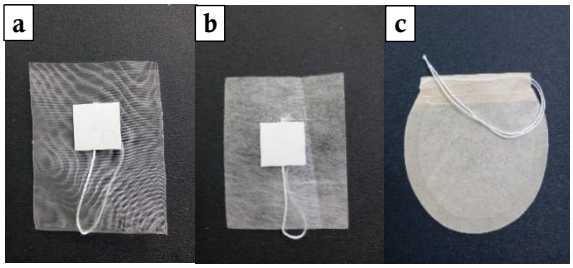


Figure 2. Tea bags (a. nylon, b. PLA, dan c. NWP)

Based on observations, that in nylon packaging cinnamon powder comes out of the bag during storage, followed by PLA packaging, and NWP. The release of cinnamon powder in nylon tea bags is due to the larger pore size. Woven nylon has an average pore size of 176.63 μm, which is three times larger than the pore size of 100% cellulose and PLA paper. Uniform and patterned fibers result in a higher average pore size (Jha *et al.*, 2020).

Cinnamal Tea Extraction

It can be observed that tea infusions with nylon and PLA bags change color to brown faster than tea infusions with NWP bags shown in Figure 3.

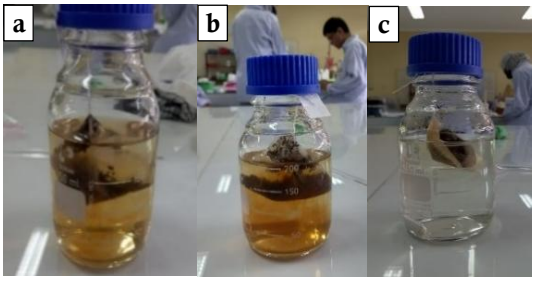


Figure 3. Tea brewing (a. nylon, b. PLA, dan c. NWP)

Several factors can affect the infusion ability of each tea bag material, one of which is the permeability of the solute (Jaganyi & Mdletshe, 2000). Permeability is the ability of tea to pass through tea bag paper by determining the permeability value, where the permeability value in tea bags made of cellulose is smaller due to the irregular pore structure, smaller pore size, and low porosity of the paper (Jha *et al.*, 2020).

The result of brewing tea with hot water produces a lemon-like aroma, which organoleptly shows that after mixing in dry conditions, essential oils are absorbed on the surface of the tea and then absorbed in the presence of hot water. These results are in line with previously reported research on aromatherapy tea preparations (Bilia et al., 2014). Infusion with water solvent aims to determine the content of volatile compounds in cinnamal tea according to the presentation by consumers. Based on the neral and geranial function groups, namely COH, both are classified as aldehyde terpenoid compounds that are slightly soluble in water and easily soluble in organic solvents (Dewi *et al.*, 2018). Therefore, the tea water is extracted with an organic solvent, n-hexane.

Concentration of n-hexane extracts is necessary to minimize the amount of solvent that is too large during GC and GCMS testing. Concentration of the sample with air containing oxygen and water vapor can react with the compounds in the test sample. In the study of Chaliha *et al.*, (2013), the concentration of volatile compounds of lemon myrtle spice in a pentane/diethyl ether solvent until the volume is reduced to 1 mL is carried out under a continuous stream of N_2 gas. Dry nitrogen is considered an inert gas; high-purity nitrogen can delay or prevent oxidation that can occur during the thickening process.

GCMS Testing on Cinnamal Tea

Based on the 0 days cinnamal tea test using GCMS, the retention time of Z-citral was about 22,442 minutes, E-citral was 24,351 minutes, and cinamaldehyde was 33,749 minutes. The column that is nonpolar causes the more polar compounds to appear first and the more nonpolar compounds to stay in the column longer. Citral senyawal is more polar than cinamaldehyde compounds. Therefore, the retention time of citral compounds is shorter than that of cinamaldehyde compounds. Analysis of the components of black and green Cinnamal tea obtained several peaks, as presented in Table 1.

Table 1. Data on the area and retention time of black and green cinnamal tea

Retention Time (min)		**Area**	
Black Tea	**Green Tea**	**Black Tea**	**Green Tea**
22,442	22,441	651136	387491
24,351	24,348	384271	456683
33,749		196222	

Based on the data in Table 1, there is a similarity in retention time at most of the detected peaks. The similarity in retention time shows that the components of the volatile compounds that make up cinnamal black tea and cinnamal green tea are the same compound. In the GCMS test of cinnamal green tea on 0 days storage, no cinamaldehyde compounds were detected. It is possible that inhomogeneity occurs after stirring in mixer tank. Green tea has a much larger size than cinnamon powder, and blends with different particle sizes have a tendency to separate, with small particles in one area and large particles in another. Thus, when sampling on day 0 of cinnamal green tea, it is likely that cinnamon powder is no longer attached to the surface of green tea or is present but in small quantities, so that what is extracted is small and not detected on the peak chromatogram.

Effect of Packaging Materials and Storage Time on Black Cinnamal Tea

Based on GC data on the storage of black cinnamal tea bags for 30 days, each of the observed volatile compounds, namely E-citral, Z-citral, and cinamaldehyde, had the same pattern on all types of packaging materials. In the three types of packaging materials with the 5 days of storage, there was a significant increase in the concentration of E-Citral compounds, which was 33%, and the pattern tended to be stable after the 10 days of storage, as presented in Table 2.

Table 2. Percent area of volatile compounds in black cinamal tea bags after storage in tea bag

Volatile Compounds	Type of Packaging	% Area of Volatile Compounds after Storage						
		0 (days)	5 (days)	10 (days)	15 (days)	20 (days)	25 (days)	30 (days)
Cinnamon								
Cinamalde-yde	Nylon	7,58	10,42	7,77	2,64	2,80	6,80	3,80
	PLA	7,58	10,28	12,28	3,68	4,02	12,34	7,98
	NWP	7,58	8,35	8,48	2,32	1,83	6,82	8,65
Lemongrass								
Z-citral	Nylon	17,92	5,19	6,40	7,97	4,08	4,95	4,47
	PLA	17,92	3,48	7,31	6,48	4,17	5,23	5,05
	NWP	17,92	5,51	4,82	7,02	8,96	7,46	5,05
E-citral	Nylon	18,35	50,87	18,97	20,20	12,28	12,81	8,15
	PLA	18,35	50,24	20,55	20,51	19,40	21,81	14,16
	NWP	18,35	55,80	86,71	18,69	13,11	15,41	10,35

PLA packaging tends to be superior to other packaging, judging from the pattern after the 10 days of storage, where the concentration of the compound is greater and more stable during the storage period. The control release of E-citral compounds in PLA packaging and nylon packaging had almost similar concentration patterns and values, but after 15 days, the concentration of E-citral compounds in PLA packaging was greater than that of nylon packaging and NWP. Whereas the concentration of E-citral in nylon and NWP packaging had almost the same value after the 15 days of storage.

Besides that, the difference in material type and storage time had no effect on the concentration of Z-citral compounds during the storage period. Based on the pattern in the table, the concentration of Z-citral compounds in all three materials tends to be the same and stable at each storage time. The concentration of Z-citral in PLA packaging is almost the same as that of nylon packaging at the time of storage. Meanwhile, in NWP packaging, the concentration of Z-citral increased slightly on the 20 days, which was 2%.

While, the difference in storage time affects the concentration of cinamaldehyde compounds. The graph pattern on all three types of materials is the same, but on the 10th and 25 days of storage, there is an increase in the concentration of cinamalde. PLA packaging tends to have superior control release capabilities during the storage period. This can be seen in the large concentration of cynamaldehyde in PLA packaging, which is larger than in nylon and NWP packaging.

This is in line with the observation that in PLA packaging, cinnamon powder does not come out of the container much during the storage period. In addition, based on research by Jha et al. (2020), regarding the influence of the type of tea bag material on the ability to infuse tea during brewing, PLA packaging provides a faster infusion rate than cellulose packaging, so it is indicated that cinnamon that remains stored in the bag will be well infused into hot water during the brewing process.

Effect of Packaging Materials on Green Cinnamal Tea

Based on the GC test of green cinnamal tea bags for 30 days storage, the compounds E-citral and cinamaldehyde have different patterns in each type of packaging material. In contrast, the type of packaging material has no effect on the concentration of Z-citral compounds during storage time. The concentration of Z-citral compounds in all three materials and at each storage time tends to be the same and stable. Different types of packaging materials affect the concentration of E-citral compounds during storage time. The control release of E-citral compounds in NWP packaging tends to be superior to other packaging, judging from the pattern after the 5 days storage, where the concentration of compounds in NWP packaging tends to be more stable and the concentration value is greater during the 30 days storage period. In nylon packaging, there was a significant decrease in concentration after the 10 days storage time, which was 70%. Meanwhile, in PLA packaging, there was a significant increase in compounds on the 15 days of storage, which was 30% as presented in Table 3.

Table 3. Percent area of volatile compounds in green cinamal tea bags after storage in tea bags

Volatile Compound	Type of Packaging	% Area of Volatile Compounds after Storage						
		0 (days)	5 (days)	10 (days)	15 (days)	20 (days)	25 (days)	30 (days)
Cinnamon								
Cinamaldeh-yde	Nylon	0.00	0.00	0.00	20.63	30.99	27.76	0.00
	PLA	0.00	19.52	14.62	14.98	29.66	28.78	19.05
	NWP	0.00	41.41	24.90	33.88	32.39	15.77	27.72
Lemongrass								
Z-citral	Nylon	14.45	9.06	7.61	5.25	4.12	5.74	7.61
	PLA	14.45	6.12	7.24	6.09	6.71	4.57	5.88
	NWP	14.45	3.21	3.82	3.50	3.14	4.20	4.49
E-citral	Nylon	85.55	86.49	87.99	18.10	17.04	17.42	45.18
	PLA	85.55	24.99	22.76	52.25	16.29	20.46	39.15
	NWP	85.55	45.56	42.34	39.21	49.29	14.90	59.94

The increase in the concentration of compounds during storage can be explained by the phenomenon of the scalping of packaging materials. In line with the research of Leelaphiwat *et al*. (2016), there was an increase in the concentration of several dominant compounds of tomyam powder in the middle of storage time using nylon, PLA, and PET packaging. Scalping is an event where the absorption of aroma compounds into the packaging occurs (Yuan *et al*., 2019).

Meanwhile, the type of packaging material affects the concentration of cinamaldehyde compounds during storage. The pattern of cinamaldehyde compounds in black cinnamal tea was also observed, with the concentration tending to be greater in NWP packaging, followed by PLA and nylon packaging. This is in line with the observation that in NWP packaging, cinnamon powder does not come out of the container much during the storage period because the average pore size of NWP bags is smaller than that of nylon and PLA packaging. In addition, in the GC test of green cinnamal tea on 0 days storage and on nylon packaging on 5 days and 10 days storage, no cinamaldehyde compound was detected.

The undetection of cinamaldehyde compounds on certain days may be due to the heterogeneity of green cinnamal tea after the mixing process in the stirring boiler tank. Green tea has a much larger powder than cinnamon powder. Blends with different particle sizes tend to separate, with small particles in one area and large particles in another. So, during the sampling of 0 days storage and the packaging of samples on the 5 days and 10 days storage of nylon packaging, it is possible that cinnamon powder is no longer attached to the surface of green tea or is present but in small quantities, so that what is extracted is small and not detected on the peak chromatogram.

Fluctuating compound concentrations during storage time can come from sample preparation factors. The difference in the number of solvents during the extraction process due to evaporation affects the concentration of volatile compounds extracted. In addition, the process of thickening n-hexane extract, which is only carried out at room temperature, can affect the components of the compounds it contains. Concentration of the sample with air containing oxygen and water vapor can react with the compounds in the test sample (Johnson, 2023).

Conclusion

Based on the results and discussions that have been described, it can be concluded that the type of packaging material and storage time affect the control release of volatile compound components in black cinnamal tea bags and green cinnamal tea. In black cinnamal tea, the control release ability of volatile compounds E-citral and cynamaldehyde in PLA (polylactic acid) packaging tends to be superior to other packaging because the concentration of compounds is larger and more stable during the storage period. Besides, in green cinnamal tea bags, the results showed that the control release ability of volatile compounds E-citral and cynamaldehyde in NWP (natural wood pulp) packaging tends to be superior to other packaging because the concentration of compounds in NWP packaging tends to be more stable with a greater concentration value during the 30 days storage period. Meanwhile, the type of packaging material and storage time had no effect on the control release of Z-citral volatile compound components in black cinnamal tea bags and green cinnamal tea. The concentration of Z-citral compounds in all three types of packaging materials and each storage time tends to be the same in black cinnamal tea and green cinnamal tea.

References

Ammari, A., & Schroen, K. (2018). Flavor Retention and Release from Beverages: A Kinetic and Thermodynamic Perspective. *Journal of Agricultural and Food Chemistry*, *66*(38), 9869–9881.

Bilia, A. R., Guccione, C., Isacchi, B., Righeschi, C., Firenzuoli, F., & Bergonzi, M. C. (2014). Essential oils loaded in nanosystems: A developing strategy for a successful therapeutic approach. *Evidence-Based Complementary and Alternative Medicine*, *2014*.

Cahyono, E., Kurniawan, C., & Anggraito, U. (2021). Vapor-solid mixer design for cinnamal tea production. *Journal of Physics: Conference Series*, *1918*(3).

Chaliha, M., Cusack, A., Currie, M., Sultanbawa, Y., & Smyth, H. (2013). Effect of packaging materials and storage on major volatile compounds in three australian native herbs. *Journal of Agricultural and Food Chemistry*, *61*(24), 5738–5745.

Dewi, L. K., Friatnasary, D. L., Herawati, W., Nurhadianty, V., & Cahyani, C. (2018). Studi Perbandingan Metode Isolasi Ekstraksi Pelarut dan Destilasi Uap Minyak Atsiri Kemangi terhadap Komposisi Senyawa Aktif. *Jurnal Rekayasa Bahan Alam Dan Energi Berkelanjutan*, *2*(1), 13–19.

González-López, M. E., Calva-Estrada, S. de J., Gradilla-Hernández, M. S., & Barajas-Álvarez, P. (2023). Current trends in biopolymers for food packaging: a review. *Frontiers in Sustainable Food Systems*, *7*(August), 1–20.

Jaganyi, D., & Mdletshe, S. (2000). Kinetics of tea infusion. Part 2: The effect of tea-bag material on the rate and temperature dependence of caffeine extraction from black Assam tea. *Food Chemistry*, *70*(2), 163–165.

Jha, D. K., Dhekne, P. P., & Patwardhan, A. W. (2020). Characterization and evaluation of tea bag papers. *Journal of Food Science and Technology*, *57*(8), 3060–3070.

Johnson, Sarah (2023, May 17). Why Nitrogen is Ideal for Drying Samples. *Organimations*. https://blog.organomation.com/blog/why-nitrogen-is-ideal-for-drying-samples

Leelaphiwat, P., Harte, J. B., Auras, R. A., Ong, P. K. C., & Chonhenchob, V. (2016). Effects of packaging materials on the aroma stability of Thai 'tom yam' seasoning powder as determined by descriptive sensory analysis and gas chromatography–mass spectrometry. *Journal of the Science of Food and Agriculture*, *97*(6), 1854–1860.

Shenoy, P., Viau, M., Tammel, K., Innings, F., Fitzpatrick, J., & Ahrné, L. (2015). Effect of powder densities, particle size and shape on mixture quality of binary food powder mixtures. *Powder Technology*, *272*, 165–172.

Tian, Q., Zhou, W., Cai, Q., Ma, G., & Lian, G. (2021). Concepts, processing, and recent developments in encapsulating essential oils. *Chinese Journal of Chemical Engineering*, *30*, 255–271.

Vallejos, S., Trigo-López, M., Arnaiz, A., Miguel, A., Muñoz, A., Mendía, A., & García, J. M. (2022). From Classical to Advanced Use of Polymers in Food and Beverage Applications. *Polymers*, *14*(4954).

Xiao, Z., Liu, W., Zhu, G., Zhou, R., & Niu, Y. (2014). A review of the preparation and application of flavour and essential oils microcapsules based on complex coacervation technology. *Journal of the Science of Food and Agriculture*, *94*(8), 1482–1494.

Yuan, S., Zhang, Y., Xie, Y., Guo, Y., Cheng, Y., Qian, H., Liu, Z., Shen, J., & Yao, W. (2019). Scalping of aroma compounds from food simulants into polyethylene terephthalate laminated steel. *Journal of the Science of Food and Agriculture*, *99*(8), 3761–3768.