Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Application of pervaporation process in the Extraction of aromatic compounds in the food industry

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ARTICLE INFO

Article History:

Received: 2024/02/08

Review: 2024/11/04

Accepted: 2026/04/11

Keywords:
Pervaporation,

Membrane technology,

Aromatic compounds

DOI: 10.48311/fsct.2026.83711.0

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ABSTRACT

The increasing trend in the consumption of food flavoring compounds has motivated the production of food flavors. Conventional techniques for the production of flavoring compounds are not sufficient in terms of quantity and variety due to the rising market demand, pervaporation as a reliable membrane process has grown rapidly compared to other conventional techniques for the recovery of aromatic compounds from agro-food systems. Pervaporation is a membrane separation process based on the use of non-porous membranes that selectively regulates the transfer of target molecules dissolved in the liquid feed mixture, and especially due to low energy consumption, no addition of chemicals to achieve separation and maintain the integrity of aromatic compounds. It has been welcomed. More than 70 different types of aromatic compounds including esters, ketones, aldehydes, alcohols, and hydrocarbons, such as ethyl acetate, ethyl butyrate, hexanal, limonene, linalool, α-terpineol, benzaldehyde, 1-3-l-octane hexanal and benzaldehyde from various sources including coffee, strawberry, cashew, kiwi juice, orange juice, plum, apple, black grape and cherry fruits, seashells were selectively recovered using PV membranes and PDMS, PEBA and POMS (hydrophobic/organophilic membranes) membranes were used for recovery. Process parameters such as extraction efficiency, feed composition, pressure, module type, feed flow rate, and feed temperature, had different effects on the number of aromatic compounds extracted from various investigated materials and most of these studies have shown the successful results of this process. However, there are still some other new membrane materials (such as PU copolymer, P(VDF-co-HFP), SBS) that should be further evaluated in this field.

1-Introduction

Today, there is an increasing demand for technological innovations in flavor and fragrance ingredients intended for use in the food, cosmetic, hygienic, and pharmaceutical industries. Flavors and fragrances constitute a broad group of chemical substances (including more than 22,000 individual molecules), such as short-chain alkanes and alkenes (with or without oxygen, nitrogen, or sulfur), alcohols, esters, ketones, and organic acids. Terpenes are likely the most abundant class of chemical compounds in nature, responsible for the characteristic aromas of plants, fruits, fungi, and animals. Typically, these organic compounds are part of the production processes of many food products, perfumes, and cosmetic–hygienic formulations [1]. To meet the current demand for such compounds, their production is commonly carried out through chemical processes involving multiple reaction steps that require costly materials and catalysts. However, there is now a strong need to replace such chemically synthesized flavors and fragrances with those extracted from natural sources [2].

At this stage, two possible routes exist for their natural production, namely: biosynthesis (through biotechnological approaches) or extraction from natural sources. The most feasible option is likely the extraction/recovery of these compounds from agricultural natural products (such as fruits, vegetables, processed foods, extracts, etc.) using appropriate separation techniques. To date, several recovery techniques have been proposed for this purpose. Primarily, all these techniques require the availability of target compounds in aqueous or solvent systems to enable separation. However, given the reactivity and stability of selected flavor and fragrance compounds, their recovery is not straightforward; indeed, most of these organic molecules are susceptible to hydrolysis, oxidation, radical reactions, and thermal degradation [3].

In this context, pervaporation, based on the use of a selective physical barrier represented by a membrane, is considered a cost-effective alternative to several classical separation processes. It offers strong potential for purifying thermally sensitive compounds in the absence of elevated temperatures or additional phases required for extraction. Today, PV is regarded as an emerging technology for various applications, such as facilitating biochemical and chemical reactions, separating solvents near their boiling points, purifying chemicals (e.g., ethanol, isopropanol, MTBE), intensifying unit operations, and isolating targeted organic molecules [2]. To date, the use of PV has expanded significantly due to its advantages (e.g., operational simplicity, high scalability, reduced number of process steps, and energy savings) over traditional extraction processes such as distillation and solvent-based extraction. Most importantly, the absence of chemical agents during extraction helps preserve the functional properties of aromatic compounds and minimizes the risk of potential contamination.

The feasibility of using PV for recovering natural aromatic compounds in the food industry is widely recognized. PV is known as a selective membrane-based process designed to meet the requirements for separating aromatic compounds. Efficient selective separation of such organic molecules from natural sources remains a current challenge due to their thermal sensitivity. Today, the research community continues to explore various selective and efficient techniques for the practical production of aromatic compounds, among which PV is a promising candidate. Several studies have also documented the successful recovery of aromatic compounds from agricultural products and food waste [3]. Therefore, the aim of this article is to provide an overview of the application of

the pervaporation technique for the extraction of flavor and fragrance compounds, as well as their derivatives, from their primary natural sources using pervaporation (PV).

2- Principles of Pervaporation

Pervaporation (PV) is a membrane separation process in which a liquid mixture (feed stream) comes into direct contact with a dense membrane. The components of the mixture, according to the selective properties of the membrane, first undergo selective sorption and then diffuse across the membrane thickness, after which the permeating component (permeate) is removed as vapor on the downstream side of the membrane (permeate stream) by means of an inert gas or by applying vacuum [4].

The transport of feed components through the membrane results from the pressure difference between the feed solution and the permeate vapor. This pressure difference can be induced in several ways. In laboratory studies, a vacuum pump is commonly used to create a pressure drop on the permeate side, whereas in industrial scale operations, cooling of the permeate vapor and generation of vacuum through its condensation is economically more feasible. A schematic representation of the PV process is shown in Figure 1 [5].

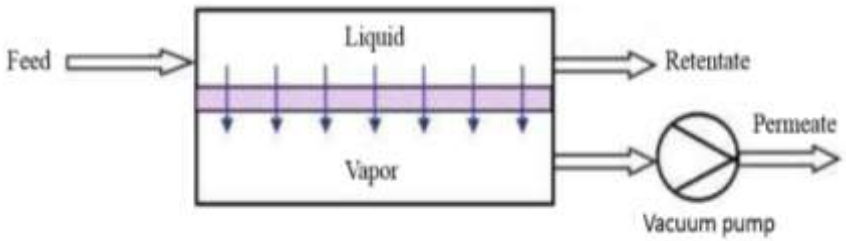

Figure 1 - Schematic of the PV process [6]

Selective liquid separation in the pervaporation process results from the preferential sorption of components as well as the diffusion of the selected component through the membrane thickness. In other words, unlike conventional non-membrane separation processes, separation in this method is based on the differences in sorption rates and diffusivities of the feed components within the membrane. Although, in theory, PV is capable of separating various liquid mixtures, in practice this process is widely applied in industry today for the separation of azeotropic mixtures, mixtures with close boiling points, and thermally sensitive organic compounds, as well as for the removal of trace impurities and, ultimately, for shifting equilibrium reactions toward completion [6].

Indeed, the independence of this process from the liquid–vapor equilibrium relationships that govern common processes such as distillation has made PV a superior alternative to earlier separation technologies. In this process, the diffusion of components through the membrane is accompanied by a phase change from liquid (feed side) to vapor (permeate side), distinguishing PV from other liquid–liquid separation methods. When valuable solutes are being recovered, PV offers several advantages over conventional separation/purification techniques (such as distillation, evaporation, adsorption, absorption, and solvent extraction), including relatively simple operation, improved scalability, reduced number of process steps, and low energy consumption [7].

In general, the applications of the PV process include dehydration of organic

solvents, removal or recovery of small amounts of volatile organic compounds from mixtures, and the separation of organic–organic mixtures. Figure 2 provides a graphical representation of a typical PV setup in which the recovery of aromatic compounds can be performed. In this configuration, the feed solution, which is in direct contact with the membrane, is separated due to the physical barrier and driving force (vacuum pressure) [8].

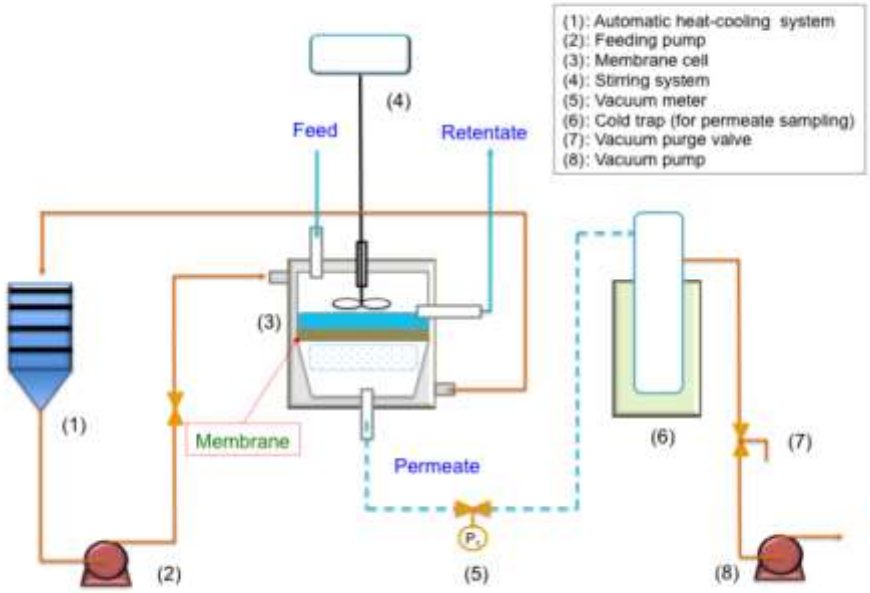

Figure 2 - Graphical illustration of a typical PV setup [4]

3-Parameters Affecting the Separation Performance of the PV Process

The degree of separation in the pervaporation process, in addition to the characteristics of the feed solution, depends on the membrane used and the operational variables of the process.

Operational conditions: Since the driving force in the PV process is the chemical potential difference, operational variables such as feed concentration, permeate pressure, and feed temperature directly influence the chemical potential. Therefore, the effect of these operational variables will alter the overall performance of the PV process [9].

Feed concentration: The term "feed concentration" refers to the concentration percentage of that component of the feed which has a higher tendency to permeate through the membrane. Changes in feed concentration directly influence diffusion at the feed–membrane interface. Because both sorption and diffusion depend on the concentration of the mixture components, the composition of the mixture has a significant impact on these two mass-transfer steps.

Feed temperature: The effect of temperature on flux can be described using the Arrhenius equation:

$$J_{i=} A_i \exp(-\frac{E_{pi}}{RT})$$

In this equation, J_i is the flux of component i, R is the gas constant, and $E_{p,i}$ is the activation energy for permeation. If the activation energy is positive, the flux increases with increasing temperature. Moreover, as the feed temperature increases, the vapor pressure of the

components on the feed side also increases, while the vapor pressure on the permeate side remains unchanged. Consequently, the vapor pressure difference which constitutes the driving force for mass transfer in the PV process increases [8].

Permeate pressure: The downstream pressure of the membrane, or permeate pressure, is directly related to the partial vapor pressure of the components, and for this reason the performance of PV strongly depends on permeate pressure. If the downstream pressure is maintained at its minimum value, the maximum driving force will be achieved. With increasing downstream pressure of the membrane, the permeate flux decreases significantly due to the reduction in driving force, while depending on the relative volatility of the permeating components, selectivity may either decrease or increase [3].

4- Suitable Membranes for the Pervaporation Process

The membrane is the core of any membrane separation process. For laboratory research, homogeneous and symmetric membranes are typically used because their fabrication is simple and they reflect the intrinsic properties of the polymers. However, at the industrial scale, those laboratory membranes that demonstrate acceptable performance are utilized in composite or asymmetric structures. These configurations, having a thin selective layer, are able to provide high flux while simultaneously maintaining their mechanical strength. The characteristics of an ideal PV membrane are as follows [10]:

1. The selective layer should be as thin as possible and free of structural defects.
2. When in contact with the feed mixture, it should exhibit high selectivity in sorption and diffusion for the target component.
3. To maintain selectivity and structural stability, it should not undergo swelling.
4. It should possess acceptable mechanical strength as well as chemical and thermal stability.
5. It should provide optimal selectivity while maintaining high flux.

The criterion for selecting a polymer for membrane fabrication is based on the solubility and diffusivity data of the different components of the mixture within the membrane polymer [11, 12].

Target Feed Mixture

Depending on the type of feed mixture intended to be separated, the membrane must be selected accordingly so that the PV process ultimately demonstrates superior performance. In PV processes, if the goal is to separate water from organic compounds, hydrophilic membranes must be used so that the major component of the permeate is water. Likewise, if the objective is to separate organic materials from water, hydrophobic membranes are considered suitable for membrane selection. Furthermore, for the separation of organic compounds from one another, the process requires organophilic membranes that can distinguish and separate the components through selective sorption and dissolution. In Table 1, the most widely used polymers categorized into three main groups based on membrane type and application in the PV process are presented [13, 14].

Table 1- Division of PV process based on the type of membrane and its application

Membrane type	Hydrophilic	Hydrophobic	Organophilic
	Polyvinyl alcohol (PVA)	Polydimethylsiloxane	Polydimethylsiloxane

	Polyacrylonitrile (PAN) Cellulose acetate Polysulfone Carboxylmethyl-cellulose Polyetherimide (PEI) Chitosan	(PDMS) Polyoctylsiloxane (POMS) Polyether-block-amide (PEBA) Ethylene-propylene diene terpolymers (EPDM) Poly-1-trymetylsilyl-1-propylene (PTMSP) Polypropylene (PP) Polybutadiene (PB) Hydrophobic zeolites	(PDMS) Polyether-block-polyamide (PEBA) Polypropylene (PP) Polyethylene (PE) Polyvinyl alcohol (PVA) Polyetherimide (PEI)
membrane type			
Applications	Breaking the azeotropes of binary mixtures	Removal of organic matter from water Removal of alcohol from alcoholic beverages Recovery of aromatic compounds from food products	Separation of methanol from MTBE Separation of benzene and cyclohexane

5- Chemistry of Aromatic Compounds and Their Role in Separation via PV

As previously stated, the chemistry and nature (hydrophilic or hydrophobic) of the target molecules play a crucial role in aroma recovery through PV. For example, lactones with fruity notes, due to their high carbon content and the presence of an oxygen-containing heterocycle, are among the most hydrophobic molecules. These molecules are, in fact, preferentially recovered by organophilic membranes. Similarly, esters, which provide primary fruity notes, are well known to exhibit a highly hydrophobic nature [15]. These molecules, containing fewer than eight carbon atoms and oxygen atoms, are highly volatile in aqueous solutions. In addition, esters represent hydrophobic molecules that exhibit almost non-hydrogen-bonding characteristics.

Alcohols and especially aldehydes are generally classified as hydrophilic organic molecules based on the presence of polar functional groups. Nevertheless, hydrophobic membranes are still good candidates for their recovery, since some of these molecules contain a benzene ring, such as benzyl alcohol, *o*-cresol, linalool, thymol, 2,5-xylenol, and benzaldehyde. Their relatively low hydrophobicity may be associated with the polar balance between the hydrophobic benzene group and the hydrophilic alcohol or aldehyde group [16].

On the other hand, sulfur compounds are more hydrophobic than their oxygen-containing counterparts. Certainly, the sulfur atom is more polarizable than oxygen, as it possesses an additional electron shell (around the atomic nucleus) compared to oxygen. In fact, hydrophobic membranes have effectively recovered certain sulfur-based compounds, including mercaptans, isobutyl thiazole, and thiobutyrate. When dealing with ketones, hydrophobic membranes have shown low selectivity for ketones with small carbon chains. This can be attributed to the pronounced hydrophilic nature of such compounds, for example, diacetyl and acetoin. Conversely, hydrophobic PV membranes (also known as organophilic membranes) are highly effective for the recovery of larger hydrophobic ketones, for

example, those containing more than six carbon atoms. Finally, there are other aromatic molecules that also exhibit hydrophilic character but can nevertheless be recovered using PV, for example, pyrazines, which provide top notes of roasted or nutty aromas [5, 17].

6- Aromatic Compounds Recovered by the PV Method

In the field of applying the PV method for recovering aromatic compounds in the food industry, various but still limited studies have been conducted to date. Table 2 summarizes the main aromatic compounds recovered by different PV membranes from agricultural food products, such as fruit juices, extracts, by-products, and several processed products (such as beer, wine, and dairy products).

Table 2. Some aromatic compounds recovered from different agricultural and food products using PV process

Aroma Compounds	Source	Membrane nature	Membrane material	Operating conditions	Productivity permeate Kg/m² h	Ref
Isobutyl acetate	Bioconversion culture broth	Hydrophobic/organophilic	POMS	30 °C 0.5 mbar	0.003	[18]
S-methyl thio-butyrate	Cauliflower Blanching water	Hydrophobic	PDMS PEBA	30 °C 2.7 mbar	0.0006 0.0002	[19]
Linalool d-Limonene 1-Heptanol 1-Hexanol Trans-2-hexenal Ethyl acetate	Blueberry model solution	Hydrophobic	PDMS	30 °C, 3.9 mbar	–	[20]
cis-3-hexenol	Tea extract	Hydrophobic/organophilic	POMS	30 °C 6 mbar	0.003	[21]
Ethyl acetate	Model solution	Hydrophobic	PDMS	25 °C, 3.9 mbar	0.008	[22]
2,3-butanedione 45 2,3-pentanedione	Model solution	Hydrophobic/organophilic	Commercial PDMS	20°C, 2.5 mbar	0.432	[20]
Vanillin	model solution	Hydrophobic	PEBA	50°C 3 mbar	0.39	[13]
β-Pinene Limonene	Lemon Juice	Hydrophobic/organophilic	POMS	30°C 0 mbar	0.0003 0.0009	[23]
Isopentyl acetate n-Hexanol α -Ionone	Pomegranate juice	Hydrophobic	PDMS	30°C 0 mbar	0.0005	[24]

1-methyl-1-pyrrole, methylpyrazine,						
Bergapten, linalool, linalyl acetate, limonene	Bergamot essential oil	Hydrophobic	Commercial GFT 1070	25-40 °C 10 mbar	0.0009	[25]
Ethyl alcohol Ethyl acetate Isoamyl alcohol Isoamyl acetate	Sugarcane molasses fermentation broth	Hydrophobic	Commercial Pervap 4060	30°C 10 mbar	0.100	[26]
Pentan-1-ol Hexanal Butyl acetate Heptan-1-ol	Plum, apple, blackcurrant and cherry hydrolysates	Hydrophobic	Commercial Pervap ECO 001 BP	60°C 3000 mbar	0.008	[27]
Benzaldehyde acetic acid	Coffee	Hydrophobic	PDMS	20, 30, and 40°C 270, 530, 800 Pa	0.006	[28]
Nerol α-terpineol linalool	Lemon essential oil waste	Hydrophobic	PDMS/PVDF	30°C, 10 mbar	0.0003 0.0009 0.0006	[29]
1-octen-3-ol hexanal benzaldehyde	Oyster	Hydrophobic	PDMS	30°C 0 mbar	0.0005	[30]
β-Ionone	Black tea	Hydrophobic	MWCNT PDMS	30°C 0 mbar	0.0005	[31]
Linalool benzaldehyde ethyl acetate	Blackberry juice	Hydrophobic	ZIF-8/PDMS	20°C 2.5 mbar	0.0009	[32]
Inalool terpinen-4-ol α-terpineol camphor	lavender	Hydrophobic	PDMS	40°C 10 mbar	0.25484	[33]

Isci et al. (2006) investigated the effect of various operating parameters, including feed temperature, concentration, composition, and permeate pressure, on the PV performance of a PDMS membrane (PERVAP 1070) in the separation of strawberry aroma compounds. The results showed that the mass flux and selectivity of aqueous methyl butyrate solution increased with increasing feed temperature or decreasing downstream pressure. The selectivity decreased with increasing feed concentration of binary aqueous solutions containing methyl butyrate and ethyl butyrate [34].

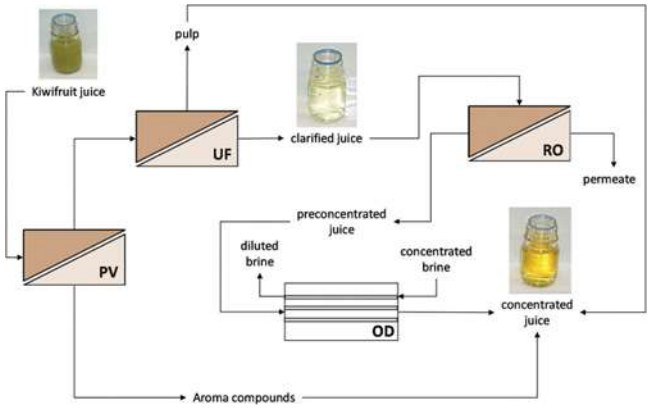

Figure 3- Integrated membrane production process for kiwifruit juice concentration UF, ultrafiltration; RO, reverse osmosis; PV, pervaporation; OD, osmotic distillation

De Assis et al. (2007) evaluated the performance of POMS membranes in the recovery of aromatic compounds from cashew apple pulp. The permeation flux ranged between 0.11 and 0.17 $kg \cdot m^{-2} \cdot h^{-1}$ at 25 °C and 35 °C, respectively. According to the results of GC–MS analyses, the concentration of aromatic compounds in the permeate samples was significantly higher than in the feed samples [35].

Hydroxyl-terminated polybutadiene (HTPB)-based polyurethane–urea copolymer membranes were highly efficient in the extraction of ethyl acetate from aqueous solution by PV, with a separation factor and total flux of 655 and 256 $g \cdot m^{-2} \cdot h^{-1}$, respectively [35].

Cassano et al. (2006) evaluated the performance of a commercial PDMS-based membrane in the extraction of aromatic compounds from ultrafiltered kiwi juice. In all PV experiments, the enrichment factors of alcohols (between 10 and 40) were lower than those of esters, such as ethyl butanoate and methyl butanoate (around 100). Moreover, for most aromatic solutes, the enrichment factor in the permeate from depectinized juice was higher than that from clarified and concentrated juice, with the exception of 3-hexen-1-ol and hexanal. Based on these findings, an integrated membrane process for the production of high-quality concentrated juice was proposed (Figure 3). The proposed scheme suggests the use of PV after the depectinization step, thereby minimizing the loss of aromatic molecules during the clarification and concentration steps. The recovered aroma compounds can be added back to the juice concentrated by osmotic distillation (OD) [36].

In contrast to the study by Cassano et al., in which commercial PDMS-based membranes were used, Figoli et al. (2010) employed composite membranes with an active layer made of styrene-butadiene-co-styrene (SBS) for the recovery of aroma compounds from kiwi juice [25]. Such membranes exhibited low aroma permeation fluxes that were strongly temperature-dependent. On the other hand, their selectivity toward (E)-2-hexenal, (E)-2-hexen-1-ol, 1-octen-2-ol, and 1-hexanol was higher than that of PDMS-based membranes. Moreover, the recovery of volatile compounds was influenced by temperature during the process. In fact, the authors concluded that 30 °C was identified as the optimal recovery temperature.

Several volatile flavor–aroma compounds (such as ethyl acetate, ethyl butyrate, hexanal, limonene, linalool, and α-terpineol) were also extracted from orange juice using PV. Specifically, the PDMS membrane exhibited a higher enrichment factor for ethyl butyrate and hexanal when the vacuum pressure was increased.

In a different approach, 3-methylbutanal and isopentyl acetate were recovered from another juice (pomegranate juice) using two different membranes. Notably, POMS, as an organophilic membrane, exhibited higher β-values for these compounds compared to PDMS. Furthermore, the authors analyzed the effect of temperature on the PV recovery process using the Arrhenius relationship. The analysis revealed positive activation energy values for the components, meaning that increasing the feed temperature may lead to higher flux. Importantly, the activation energies of the aromatic compounds were higher than that of water, indicating that the diffusion of aromatic compounds through the membrane is more temperature-dependent than that of water. Generally, when the activation energy is high, the flux becomes more sensitive to temperature changes; therefore, aromatic compounds tend to exhibit higher temperature sensitivity [37].

In the fruit sector, there also exists an aromatic solution recovered from fruit juice known as fruit-water hydrolate or aromatic water. These hydrolates are highly diluted aqueous solutions in which the concentration of volatile aroma compounds does not exceed 1 wt%. Such trace-level aromatic compounds are well suited for separation by PV. Dawiec-Liśniewska et al. (2018) investigated the concentration of natural aromatic compounds from fruit-water hydrolates by PV at the laboratory scale, in which both process optimization and the economic feasibility of aroma recovery were extensively examined and analyzed.

The hydrolates originated from plum, apple, blackcurrant, and cherry, each containing a wide spectrum of aromatic components. The authors identified and quantified approximately 38 compounds in blackcurrant hydrolate, while 20 and 14 different compounds were found in apple and cherry hydrolates, respectively. The commercial hydrophobic membrane Pervap 4060 exhibited very high β-values for several compounds, such as pentan-1-ol (β = 5800), hexanal (β = 3678), butyl acetate (β = 8602), and heptan-1-ol (β) [27].

In contrast to natural products and their by-products, some processed products from the beverage industry have also been considered for the recovery of aromatic compounds, such as beer and wine. Catarino et al. (2009) proposed beer as a potential source of specific alcohols (such as propanol, isobutanol, isoamyl alcohol), esters (such as isoamyl acetate, ethyl acetate), and aldehydes (such as acetaldehyde). Initially, the recovery of these aromatic compounds was required to meet the organoleptic criteria of alcohol-free beer, which are typically compromised during ethanol removal [38].

Extensive studies have also been conducted on coffee aroma. In these studies, the performance of the PV process for the recovery of aromatic compounds has been evaluated using coffee beverages and industrial instant coffee. Hernandes et al. (2020) aimed to assess the PV process in diluted aqueous solutions of two coffee aroma compounds. The effects of temperature, concentration, feed composition, and permeate pressure on permeation flux and selectivity were investigated. The selected compounds were benzaldehyde and acetic acid, which have both positive and negative impacts on the sensory quality of coffee. According to the results, all permeation fluxes increased with temperature, following an Arrhenius-type relationship, in which temperature has a stronger effect on diffusion than on sorption.

The enrichment factor of benzaldehyde increased with temperature at 270 Pa but remained nearly constant between 30 and 40 °C at 530 and 800 Pa. Therefore, the PV process for benzaldehyde should be operated at lower pressures and higher temperatures. As the feed concentration increased, the individual fluxes of the

organic compounds increased linearly; however, the enrichment factors of both compounds remained nearly constant. For the ternary system benzaldehyde–acetic acid–water, a reduction in flux and enrichment factors was observed for both benzaldehyde and acetic acid, and this reduction was more pronounced at higher concentrations. This suggests that the presence of another organic molecule negatively influences the pervaporation performance of both compounds. Benzaldehyde was more sensitive to changes in feed composition across all studied concentrations [28].

Oysters, with an annual global production exceeding 600,000 tons, represent an important portion of shellfish consumption worldwide. These bivalve mollusks have high commercial value but are highly perishable due to their high microbial load, including pathogens that can cause illness or even death when consumed raw. Therefore, heat treatments are used to increase the safety of this seafood for human consumption. However, some steps in this process can generate wastewater such as the water used in cooking that is rich in volatile organic compounds originating from oysters. After recovery and concentration, these compounds can be used as natural seafood flavorings.

In a study, Soares et al. (2020) evaluated the application of the pervaporation membrane process for the recovery of aromatic compounds from oysters (Figure 4). The characteristic aromatic compounds 1-octen-3-ol, hexanal, and benzaldehyde were selectively concentrated from oysters, demonstrating the practical applicability of this technology for the food industry, as they can be used as natural flavorings in processed seafood products. Feed temperature had little effect on the permeation flux of trichloromethane and hexanal, whereas higher enrichment factors for benzaldehyde and 1-octen-3-ol were obtained at 30 °C and 40 °C, respectively.

Computational fluid dynamics (CFD) simulation of flow inside the permeation module showed that the flow regime was laminar at all flow rates and temperatures used in the study. Although higher fluxes were obtained at lower permeate pressures, the highest enrichment factors (35 for 1-octen-3-ol) were achieved at intermediate permeate pressures (1750 Pa), which may positively influence process economics. Ultimately, the results of this study demonstrated that the pervaporation process is highly promising for adding value to a waste stream in the seafood industry [30].

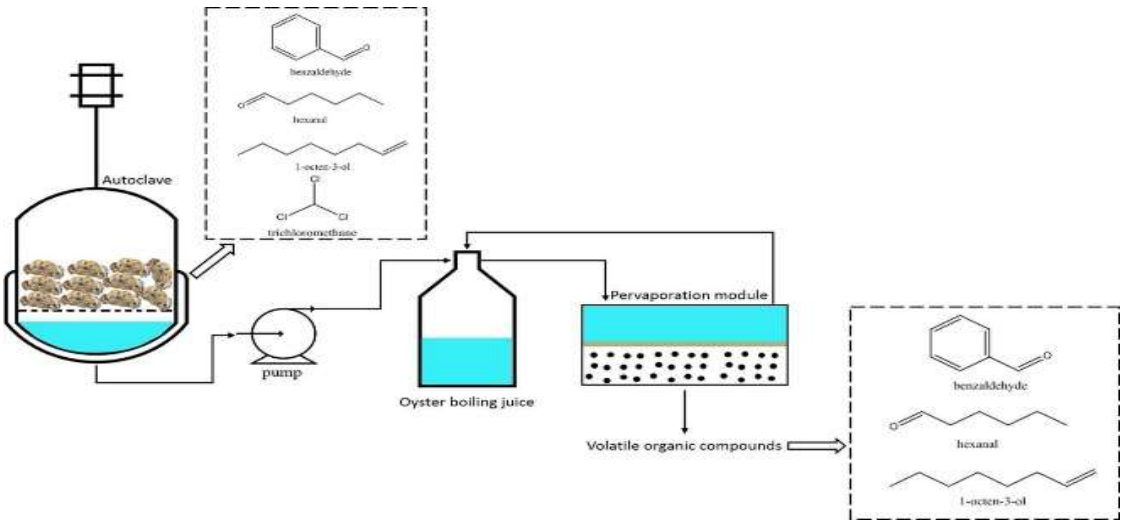

Figure 4- Schematic of the recovery process of aromatic compounds from oysters by PV method [30].

7- Conclusion

In this article, the potential of the pervaporation process for the recovery of aromatic compounds was examined, and most of the studies reviewed demonstrated the successful performance of this process. In fact, more than 70 different types of compounds (including esters, ketones, aldehydes, alcohols, and hydrocarbons) have already been separated and selectively recovered from various sources using PV membranes. To date, it appears that PDMS, PEBA, and POMS have been the most widely used hydrophobic/organophilic membranes for such recovery tasks. However, several other emerging membrane materials (such as PU copolymers, P(VDF-co-HFP), and SBS) still require further evaluation in this field.

Certainly, membrane specialists are actively working on the development of new membrane materials or the improvement of existing ones to overcome the trade-off limitations between selectivity and permeation flux. Research is currently being conducted on the implementation of PV technology as a primary tool for recovering aromatic compounds. Moreover, the apparent global increase in demand for these volatile and aromatic compounds in the food, cosmetic, and pharmaceutical industries may further promote the adoption of this technology.

Conflict of Interest

There are none to declare.

Funding Statement

This research has not received any specific financial support from government, commercial, or non-profit institutions.

Author Contributions

All authors have contributed to the design, analysis, writing, and approval of the final manuscript in this manner

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مقاله علمی_پژوهشی

بررسی کاربرد فرآیند تراوش تبخیری در استخراج ترکیبات معطر در صنایع غذایی

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اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۲/۱۱/۱۹

تاریخ داوری: ۱۴۰۳/۰۴/۱۸

تاریخ پذیرش: ۱۴۰۵/۰۱/۲۲

کلمات کلیدی:

تراوش تبخیری،

فرآیند غشایی،

ترکیبات معطر

DOI: 10.48311/fsct.2026.83711.0

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چکیده

روند رو به افزایش مصرف ترکیبات طعم‌دهنده غذا باعث ایجاد انگیزه در تولید طعم‌های غذایی شده است. تکنیک‌های مرسوم تولید ترکیبات طعم‌دهنده با توجه به تقاضای صعودی بازار ازنظر کمیت و تنوع کافی نیست، تراوش تبخیری به‌عنوان یک فرآیند غشایی معتبر، نسبت به سایر تکنیک‌های مرسوم، برای بازیابی ترکیبات معطر از سیستم‌های غذایی کشاورزی، رشد سریعی داشته است. تراوش تبخیری فرآیند جداسازی غشایی بر اساس استفاده از غشاهای غیر متخلخل است که به‌طور انتخابی انتقال مولکول‌های هدف حل‌شده در مخلوط خوراک مایع را تنظیم می¬کند و به‌ویژه به دلیل مصرف انرژی کم، عدم افزودن مواد شیمیایی برای دستیابی به جداسازی و حفظ یکپارچگی ترکیبات معطر، مورد استقبال قرار گرفته است. بیش از ۷۰ نوع مختلف از ترکیبات معطر ازجمله استرها، کتون‌ها، آلدئیدها، الکل‌ها، هیدروکربن‌ها، اتیل استات، اتیل بوتیرات، هگزانال، لیمونن، لینالول، α-ترپینول، بنزآلدهید و ۱-۳-ال- اوکتان هگزانال از منابع مختلف از جمله قهوه، توت فرنگی، بادام هندی، آب کیوی، آب پرتقال، میوه‌های آلو، سیب، انگور سیاه و گیلاس، صدف دریایی به‌طور انتخابی با استفاده از غشاهای تراوش تبخیری (PDMS، PEBA و POMS (غشاهای آب‌گریز/ارگانوفیل)) بازیابی شدند. پارامترهای فرآیند مانند بازده استخراج، ترکیب خوراک، فشار، نوع ماژول، سرعت جریان خوراک، دمای خوراک، اثرات متفاوتی بر مقدار ترکیبات معطر استخراج شده از مواد گوناگون مورد بررسی داشتند. اکثر این مطالعات نشان دهنده نتایج موفقیت آمیز این فرآیند بوده است، بااین‌حال، هنوز برخی از مواد غشایی جدید دیگر (مانند کوپلیمر PU، P(VDF-co-HFP)، SBS) وجود دارد که باید در این زمینه بیشتر مورد ارزیابی قرار گیرند.