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Research Article

Cloud Point Extraction: A Novel Approach for Extraction of Bioactive Compounds from Fruit and Vegetable Waste

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Abstract

Food processing sector has experienced a revolutionary development for environment friendly and efficient technologies for extraction of food bioactive compounds due to the technical, scientific and economical headrace of traditional extraction techniques. These bioactive are vital nutrients that are present in very small quantities in food. In biological system, these components have a broad range of action such as antioxidant, metal chelator, antiallergic, antimicrobial, and clarifying agents. Cloud point extraction is a green technique for extraction of bioactive components from thermally sensitive processing food and waste. It is a simple, rapid and inexpensive novel extraction technique over traditional method without affects surrounding environment. This articles aims to provide the brief information about cloud point extraction technique as a green extraction of bioactive compounds from food and processing waste.

Keywords: Cloud point extraction, food processing, green technology, bioactive components

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Introduction

Fruits and vegetables play an important role in our diet, and as a result of the increasing world population and evolving preferences, demand for these essential food resources has increased significantly. Increased food production, and lack of adequate methods of handling and facilities have resulted in huge losses and waste of these food resources and their bioactive components. Losses and waste of horticultural commodities are the highest among all types of foods, reaching up to 60% [1]. Cloud point extraction (CPE) is a novel technique for extraction of thermally-sensitive bioactive components from food and waste in an energy efficient manner. Using surfactants, CPE can be used to remove wide variety of organic and inorganic components. It is a technique involving the clustering of non-ionic surfactant monomers to form a hydrophobic center (micelle) that then traps the bioactive hydrophobic compounds within it [2]. Until recently, extracting phenolic compounds from wastes was not only difficult and costly but also not environmentally friendly, as it requires large quantities of toxic and flammable organic solvents. Other extraction methods such as liquid-solid phase extraction, solid-phase extraction, supercritical fluid extraction, ultrasonically assisted solvent extraction, and accelerated pressurized and microwave-assisted extraction techniques are not satisfactory for analytical purposes in dietary applications because they results in lower phenolic recovery and require expensive equipment or high energy demand [3]. CPE has several advantages over conventional extraction techniques which include elimination of purification, concentration, and cleaning steps commonly required in conventional extraction. It use of a non-toxic surfactant along with smaller amount of chemicals. It can simultaneously extract multiple compounds with mild extraction conditions. It also has lower probability of emulsion formation while extraction and compatibility with wide range of food matrices [4].

Cloud Point Extraction (CPE)

Definition of CPE

CPE is a method of extracting hydrophobic bioactive compound from food and processing waste using nonionic surfactant which is nontoxic in nature and environmental friendly [5].

The principle and process of CPE

In CPE, a micellar (surfactant-rich) phase is added to the sample which is originated from homogeneous surfactant solution. A non-polar core is developed due to its hydrocarbon tails towards the center by a micelle. In hydrophobic center of micelles,then, the seperaion of bioactive compounds takes place. During heating, cloud is generated due to nonionic surfactants. Then, these clouds form two isotropic phases which coexist. As illustrated in **Figure 1**, at a particular temperature, also known as clouding point temperature; surfactant-rich and surfactant-lean phase are created as a result of physical change in the homogeneous solution of amphiphilic substances and a cluster is created due to the attraction [2].

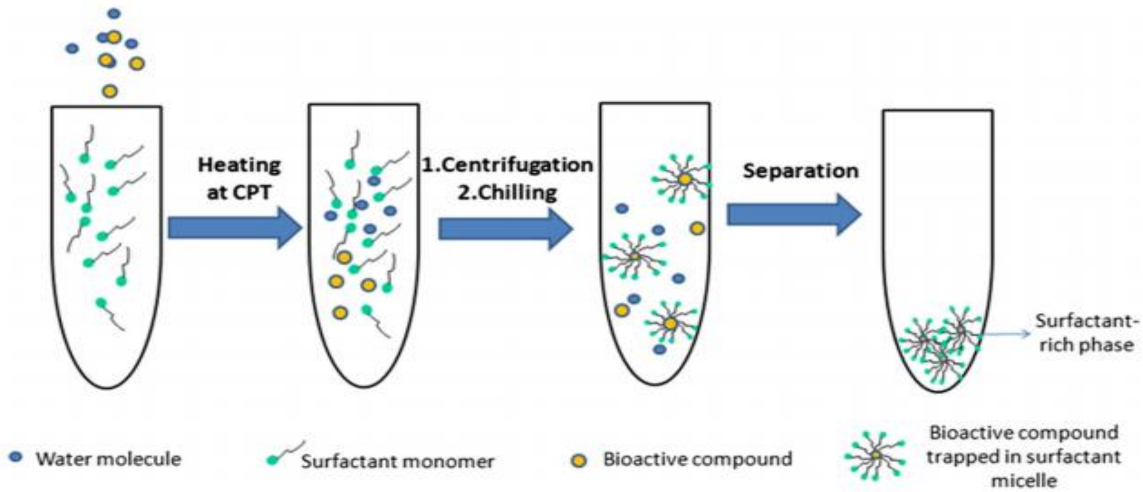

Figure 1 Process of CPE

The process by which this separation happens is attributed as a result of the rise in temperature, leading to the rapid increase in aggregation number of micelles of the surfactant. This effect causes a decrease in effective area of the micelle surface occupied by the polar group, increasing the size of the micelle which can be considered infinite at the cloud point, resulting in phase separation [6].

Terms used in CPE process:

Surfactant

Surfactants are amphiphilic organic substances. Their molecules have a long hydrophobic hydrocarbon chain and a small charged or hydrophilic polar ring. A typical surfactant has an R-X structure, where R is a chain of hydrocarbons that can have between 8 and 18 carbon atoms, and X is the polar or ionic head group. The most common chemical surfactant classification is based on the composition of the hydrophilic group. The four general groups of surfactants are defined as non-ionic, cationic, anionic, and amphoteric (or zwitterionic) [7, 8]. The characteristics of the micelle system change according to the types of surfactant used for extraction. Non-ionic surfactant’s polar chain contains hydrophilic groups which form intermolecular hydrogen bonding with water. Additives and improvers can alter the critical (CMC) values of the surfactants. The phase separation will occur above the temperature of the cloud point (CPT), which is increased with deceased in molecular mass and hydrophobic tail branching. With the addition of neutral electrolyte (sulphates, carbonates) and polar organic compounds (aliphatic alcohols, fatty acids), the CPT is observed to decrease. Conversely, adding salt in form salt (nitrates, thiocynates) increases cPT. Some of the commonly used non-ionic miceller mediums are Triton X-45, Triton X-100 and Triton X-114 [9].

Cloud point temperature (CPT)

At a specific temperature surfactant-rich and surfactant-lean phases are formed due to physical change in the homogeneous solutions of amphiphilic substances is called cloud point temperature [6].

Phase separation

After heating to a temperature known as the cloud level, aqueous solutions of most nonionic surfactant micelles become turbid. Above this temperature, the solution separates into two phases one, very small in volume, composed almost totally of the surfactant with a small amount of water (referred to as the surfactant-rich or coacervate phase) and the other, the bulk aqueous solution (aqueous phase) in which the surfactant concentration will be approximately equal to its critical micelle concentration (lean or dilute phase) [4].

Critical micellar concentration (CMC)

In aqueous solution, Surfactant unimers are self-assembled into micelles at a particular concentration called the critical micelle concentration. Above the CMC, the unimer concentration remains the same; the additional surfactants just form more and more micelles [10]. It is the particular concentration beyond which, the surfactant monomers combine in a configuration with the minimum energy.

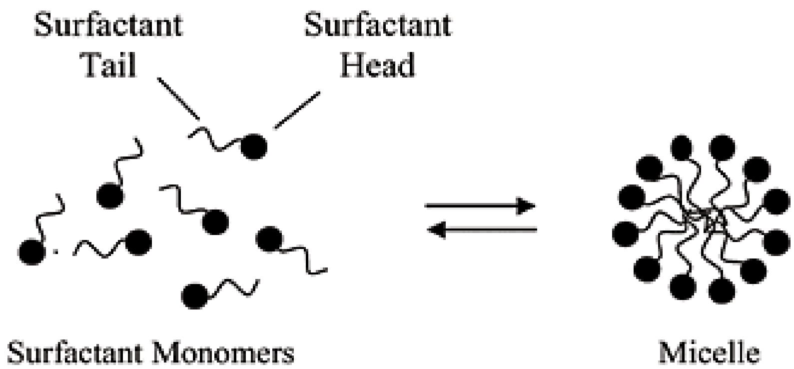

Figure 2 Reversible monomer micelle thermally equilibrium [11]

CPE component determination methods

Determination of critical micelle concentration (CMC)

The most popular method of calculating cmc is surface tension. This also includes the details on the important surface properties of surfactant. Due to low concentration, surfactant monomers inhibit the degree of intermolecular hydrogen bonding between water molecular at the interface of the solution. It gradually decreases the water molecular interfacial tension with rising concentration of surfactants until the solution interface is saturated with amphiphiles. Further than complete interfacial saturation, surfactant self-able to form micelles and combine essentially the bulk phase without perturbing the interfacial rheology. The concentration of surfactant at the breakpoint indicates interfacial saturation and the interfacial saturation is considered to lead to amphiphile self-aggregation (or micellization). Therefore the break point is a function of cmc [12].

Determination of cloud point

The cloud point for the various surfactant solutions can be calculated by observing the temperature needed for the onset of turbidity when heating an aqueous surfactant solution in a small test tube that was placed in a controlled water/antifreeze bath. The phase diagrams can be obtained by calculating the temperature of cloud point according to the concentration of surfactant [13].

Determination of phase volume ratio

The ratio of the volumes of the surfactant-rich phase to the aqueous phase (V_s/V_w) for each system under different conditions can be determined by placing the surfactant solution into an NMR tube and conducting the extraction. Following phase separation, the height of each phase in the NMR tube can be measured and the phase volume ratio can be calculated by comparing the heights of the two phases [14].

Applications of cloud point extraction in food processing

CPE is one of the promising novel techniques for extraction of functional components due to their mild conditional requirements. Use of CPE for extraction of polyphenols from industrial waste is one of the most important applications in food processing. CPE can be used to extract bioactives from food processing waste, as well as to isolate and purify proteins. In addition, it has been paying careful attention to preparing samples for study of food constituents in the last decade (2). Papaioannou and Karabelas (2012) studied the extraction of lycopene from the tomato peel residues which usually create from the tomato processing industry [15]. Combined treatment result in a nearly fourfold recovery of lycopene compared to simple 1 h enzymatic pretreatment and about tenfold higher than recovery from untreated peels. Chatzilazarou et al. (2010), investigated Removal of Polyphenols from Wine Sludge Using Cloud Point Extraction and Result found that for each surfactant GenapolX-080 and PEG 8000 high phenol recovery values were achieved 75.8% or 98.5%, respectively from wine sludge [3]. Katsoyannos et al. (2012) did the evaluation of the suitability of low-hazard surfactant Tween 20, Tween 80, Span 20, and PEG 400 in the separation of natural antioxidants (phenols and carotenoids) found in olive waste water (OMW) and red-fresh orange juice (RFOJ) [16]. Result showed that Tween 80 showed the highest recovery and a double step CPE with 5% + 5% of Tween 80 recovered up to 94.4% of the total phenols from olive mill wastewater, while a 7% + 7% of Tween 80 recovered up to 72.4% of the total carotenoids from orange juice.

Advantages of cloud point extraction

CPE has following advantages over conventional extraction techniques;

- It eliminates the purification, concentration, and cleaning steps commonly required in conventional extraction
- It uses the non-toxic surfactant
- A smaller amount of chemicals is required for cloud point extraction process
- Options exist for simultaneous extraction of multiple compounds
- Works under mild extraction conditions
- Lower probability of emulsion formation while extraction
- This process is compatible with wide range of food matrices

Conclusion

CPE technique provides an interesting and efficient environmentally friendly alternative to other phenolic compounds extraction method of due to its simplicity, less operation time, easy employment and simple equipment requirements. Besides, extraction of bioactive compounds from food, research has received special attention on sample preparation for analysis of food constituents. Considering its wide range of applications and advantages over conventional extraction techniques, it can be therefore concluded that there are several possibilities of extending applicability of CPE in food processing.

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