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Review

Influence of drying on functional properties of food biopolymers: From traditional to novel dehydration techniques

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ABSTRACT

Background: Drying is a complex process frequent in most of the food processing industries. The functional properties of food components, highly affected by the drying processes, significantly influence the scope of their application and commercial value. Food biopolymers such as proteins, carbohydrates, and mixed flours are important due to their functional properties including water solubility, swelling index, water/oil holding capacity, porosity, emulsification, foaming, bulk density, viscosity and gel properties.
Scope and approach: This review study goes over the relationship between miscellaneous drying treatments applied on food biopolymers in research works carried out during the last two decades. It not only outlines the effect of drying/heating treatments on diverse biopolymers, but also compares the effect of each one (oven, sun, shade, solar, tray/cabinet, vacuum, freeze, fluidized bed, drum, and spray drying) on macromolecules of food products with each other, and monitors microstructural changes brought about by those methods. Finally, it summarizes the influence of novel dehydration techniques (assisted by microwave, ultrasound, infrared, vacuum impregnation, and phosphorylation through dry heating) being applied these days for the successful drying of food products to give a direction to experts following this topic in oncoming years.
Key findings and conclusions: Our comparisons show that among conventional drying approaches for processing of protein resources, freeze drying could be more efficient than other methods while spray drying might have similar or better performance. High drying temperatures decrease the swelling capacity of carbohydrates and increase their susceptibility to breakdown during hydrothermal processes. For drying of carbohydrate sources, fluidized bed, especially at low temperatures, oven and freeze drying could yield final powders with higher functional qualities. Foam-mat, sun and freeze drying could yield better final functional properties of dried flours than oven, solar, cabinet/tray and hot air drying approaches. With microwave drying, functional properties, as opposed to nutritional qualities, could be maintained more effectively than other drying techniques, e.g. freeze drying. While application of infrared, as a novel dehydration technique, might not improve functional properties of food powders in comparison with other superior drying techniques, vacuum impregnation, another novel drying approach, could result in high saving of functional ingredients in food powders, higher anthocyanin content and better antioxidant properties of the final product.

1. Introduction

A food system is characterized by several physicochemical properties. Functional properties could be affected by the food system during different stages of food preparation, processing, storage and consumption (Sikorski, 2002). A wide range of functional properties are delivered mainly by proteins, saccharides and lipids due to their structural characteristics. Mentioned components, alone or by interacting with other food constituents,

Abbreviations: WH/AC, water holding/absorption capacity; OH/AC, oil holding/Absorption capacity; EAI, Emulsification activity index; ESI, Emulsification stability index; FC, Foaming capacity; FS, Foaming stability; PV, Peak viscosity; FV, Final viscosity; BV, Breakdown viscosity; CI, Compressibility index; LGC, Least gelatinization concentrate; WS, Water solubility.

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contribute to the desirable sensory characteristics of the final product. In addition to the nutritional quality which needs to be conserved while the food is being processed, it seems elegant to define the sensory properties, either directly through tasting or indirectly by establishing appropriate relationship with functional properties which are easier to measure (Table 1). The functional properties of food biopolymers make it possible to manufacture products of desirable quality. For example, polysaccharides are good thickening and gelling agents at different ranges of acidity and concentration of various ions (Hardacre & Clark, 2006). Some starches are resistant to retrogradation, thereby retarding staling of bread. Fructose retards moisture loss from biscuits. Mono- and diacylglycerols, phospholipids, and proteins are used for emulsifying lipids and stabilizing food emulsions and foams: Unfavorable ice formation in various products could be diminished by antifreeze proteins (Haard, 2001), creating distinctive texture of wheat bread is one of the responsibilities of gluten, and foam structure of whipped cream or some essential phases in food emulsions are controlled by lipids (Irimescu, Yasui, Iwassaki, Shimidzu, & Yamane, 2000).

The functional properties are defined as those properties which determine the overall behavior of foods during production, processing, storage and consumption. Such properties might include water holding capacity of foods (the ability to hold its own and added water during different processes), oil binding (mainly attributed to the physical entrapment of oil), emulsification (the surface properties and reduction in the interfacial tension between the hydrophilic and hydrophobic components in the food), foam capacity (the procedure of incorporating air to form a stable structure), gelation (linking protein and carbohydrate chains by the hydrogen bonds to form a network of three dimensions encircled water molecules cluster), whipping capacity (entrapping air into the system while maintaining the body of the foam), and viscosity (food resistance to gradual deformation by shear stress or tensile stress). Food quality parameters (nutritional, sensory, physicochemical and organoleptic properties) and food process indices, e.g. machinability of cookie dough or slicing of processed meats, are governed by functional properties; therefore, these properties are important in product processing and food product formulation (Kinsella, 1979; Wu, Wang, Ma, & Ren, 2009).

The aim of this review is to focus on the influence of drying on functional properties of different macromolecules such as proteins, polysaccharides and other biopolymers and also present necessary theoretical and practical information on this process. Thus, we will cover the relationships between various drying methods consisting of spray drying, freeze drying, sun drying, hot air drying, vacuum drying, oven drying, ethanol precipitation, microwave drying, tray drying, and drum drying and functional properties of different food components. First, to better understand the influence of drying process on functional properties, the factors affecting the structure and functional properties of the macromolecules are discussed. Then, the effect of (traditional) drying conditions, such as dryer type and different temperatures, on the functional properties (water solubility, swelling index, water/oil holding capacity, porosity, emulsion and foaming properties, bulk density, viscosity and gel properties) of biopolymers will be explained and compared. Then, the underlying causes of these effects will be inspected in the microstructure of those macromolecules (carbohydrates, proteins and flours). The last part of this article summarizes recent findings about the effects of novel drying techniques (assisted by microwave, ultrasound, infrared, vacuum impregnation, and phosphorylation through dry heating) on the functional properties of food products.

2. The role of different food biopolymers on functional properties

It is important to understand how biopolymer concentration, configuration, size and polydispersity affect functional properties of foods which are very critical industrially. Proteins are being increasingly used as food ingredients. The functional properties of food proteins are important in food processing and food product formulations. However, their ability to improve functional properties, such as solubility, water absorption, gelation, foaming, and emulsification, of food products is a determinant benchmark for their more usage.

Naturally, polysaccharides (carbohydrates) are utilized as a source of energy, structure-forming material, and water-maintaining hydrocolloids. Food producers pay particular attention to the major structural changes which occur as a result of heating during processing that could lead to a change in the functional behavior of carbohydrates. Furthermore, there is an additional task for some carbohydrate substances such as gums (gum Arabic, xanthan, locust bean gum, and β-glucan), except the routine duty of stabilizing food structures like foams: involving in the firmness of protein systems (Burkus & Temelli, 2000; Makri & Doxastakis, 2006) since it is assumed that they incline to proceed to the interface and dwindle the interfacial tension, thereby playing a major role in the solidity of foams (Sciarini, Maldonado, Ribotta, Perez, & Leon, 2009). In other words, suitable comprehension of the carbohydrate phase transitions, gelatinization and their other functional properties is crucial in food processing (Roos, 1995). Starch, also, is the most considerable resource of carbohydrates in foods, comprising 80–90% of all polysaccharides used in our diets,

Table 1
Relationship between functional and sensory properties of foods (Adapted from Linden et al., 1999).

Functional properties		Physical conditions	Sensory properties
Adsorption	Flavor binding Fat adsorption capacity Water holding	Gas	Flavor
Interfacial	Bulking Emulsification	Foam Two phase liquid	Observation
Hydration	Water holding Swelling Solubility Viscosity	Paste	Kinesthetic properties
Texture	Porosity Aggregation Coagulation Elasticity Microstructure (cellular)	Dispersed solid Compact solid	Touch rheology Hearing, Observation