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Effects of drying and grinding in production of fruit and vegetable powders: A review

Marie Céleste Karam [a, *], Jeremy Petit [a], David Zimmer [a], Elie Baudelaire Djantou [b], Joël Scher [a]

[a] Université de Lorraine, LIBio (Laboratoire d'Ingénierie des Biomolécules), 2, avenue de la Forêt de Haye, TSA 40602, 54518 Vandœuvre-lès-Nancy, France
[b] AGRITECH, France, 4, Rue Piroux, 54000 Nancy, France

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ABSTRACT

In recent years, fruits and vegetables have received considerable attention, as these materials have been reported to contain a wide array of phytochemicals, which are claimed to exert many health benefits including antioxidant activity. In some cases where bioactive compounds extraction cannot be performed on fresh products, drying appears as a necessary step enabling their later use. Drying is a widely used food preservation process in which water removal minimize many of the moisture-driven deterioration reactions impacting the bioproduct quality. Dried fruits and vegetables and their application in powder form have gained interest in the food industry. Drying and grinding conditions during powder processing greatly influence the quality attributes of biological materials. It implies not only nutritional changes but also physical, textural, sensorial and functional changes. These changes are of great importance and require to be controlled through retroengineering approaches. This paper reviews the effect of the different dry drying and grinding methods on the physicochemical and functional properties of the final products. Overviews of some of the innovative concepts as well as approaches to alleviate the above-mentioned changes are discussed.

Contents

* Corresponding author.
E-mail address: marie-celeste.techer@univ-lorraine.fr (M.C. Karam).

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Nomenclature:

ADG	Alternation of Drying and Grinding
CD	Convective Drying
DD	Desiccant Drying
DIC	Détente Instantanée Contrôlée
DIS	Dewatering Impregnation Soaking in concentrated solutions
EHD	ElectroHydrodynamic Drying
FD	Freeze Drying
HAD	Hot Air Drying
HPD	Heat Pump Drying
IRD	Infrared Drying
MW	Microwave
MWD	Microwave Drying
MWAD	Microwave-assisted air drying
MWFD	Microwave-assisted freeze drying
MWVD	Microwave-assisted vacuum drying
OD	Osmotic Dehydration
OH	Ohmic
PEF	Pulsed Electric Field
RFD	Radiofrequency Drying
RWD	Refractance Window Drying
$scCO_2D$	Supercritical Carbon Dioxide Drying
SSD	Superheated Steam Drying
VD	Vacuum Drying

1. Introduction

Fruits and vegetables have proved to be essential for a balanced diet. Epidemiological and clinical investigations have actually associated diets rich in fruits and vegetables with reduced risks of cardiovascular, coronary heart, metabolic and degenerative diseases, as well as certain form of cancers (Saleem et al., 2002; Zhang et al., 2005a,b; Dai et al., 2006; Chen et al., 2006). This is believed to be mainly due to their content in fibers, vitamins, minerals and phytochemicals, such as polyphenols, flavonoids, sterols, carotenoids, chlorophylls, anthocyanins, etc., responsible in part for their strong antioxidant activity (Andersen and Jordheim, 2006; Siriamornpun et al., 2012). Indeed, these bioactive compounds are known to chelate metal ions (such as iron and copper), donate hydrogen atom and scavenge harmful free radicals associated with chronic diseases, protecting thus human tissues and cells from oxidative damages (Edge et al., 1997; Heim et al., 2002; Johnson, 2002; Balasundram et al., 2006). Fresh fruits and vegetables are highly perishable commodities (due to their high moisture content around 80%) that deteriorate over a short period of time if improperly handled (Orsat et al., 2006). Drying fruits and vegetables is a process where water removal halts the growth of spoilage microorganisms, as well as the occurrence of enzymatic or nonenzymatic browning reaction in the material matrix (Zhang et al., 2006; Argyropoulos et al., 2011; Kurozawa et al. 2012) preserving thus the structure, sensorial characteristics and nutritional value of the starting material (Aguilera, 2003). The market for dehydrated fruits and vegetables has actually known a rapid growth rate (of 3.3%) for most countries worldwide (Zhang et al., 2006). Dried fruits and vegetables are widely used by the confectionary, bakery, sweet and distilling industries in various sauce, teas, puddings, garnishments and food for infants and children. Applications particularly include fruits and vegetables powders used as intermediate products in the beverage industry, as functional food additives improving the nutritional value of foodstuff, as flavoring agent (in ice creams, yogurts, fruit bars) or also as natural colorants (Camire et al., 2007). Camire et al. (2007) have described for example a more attractive white cornmeal breakfast cereal when blueberry and cranberry fruit powders were added as colorants. Correia da Costa et al. (2009) have highlighted the usefulness of guava and cashew-apple powders in food industry as high dietary fiber ingredients fortifiers. Fruit and vegetable powders likewise serve as ingredients in instant noodles, dried soups and other food recipes (Nindo et al., 2003a,b; Argyropoulos et al., 2011; Zhang et al., 2012). Their use in perfumery and cosmetics (such as *Kaempferia galanga* powder for instance) as well as resources for nutraceutical has also been reported (Correia da Costa et al., 2009; Chan et al., 2009). The quality of a fruit/vegetable powder is highly dependent upon the drying/grinding medium and conditions, as well as the composition, physical properties, production system (conventional or organic) and cultivar-field (mechanically or hand harvested) of the raw material (Sablani, 2006; Rahman et al., 2009; Sablani et al., 2011). Quality degradations like shrinkage, puffing, crystallization, decrease in rehydration capacity and losses of taste, aroma, color and nutritional values are the main problems encountered and to be solved through dry drying and grinding processes (Devahastin and Niamnuy, 2010; Sablani, 2006; Zhang et al., 2012). This paper primarily aims at comparing the different (traditional and novel) dry drying processes. Some approaches to minimize the adverse effects of processing and enhance the quality of final products are also discussed.

2. Effect of dry drying methods on overall quality of fruit and vegetable powders

2.1. Dry drying of fruits and vegetables

Drying is one of the oldest, most common and most diverse food processing methods. It is a complex process involving simultaneous heat and mass transfer requiring precise process control (Mujumdar & Passos, 2000). Drying a moist material implies evaporation of both free and loosely bound water from inside the solid material into the atmosphere. The latent heat of vaporization may be supplied by convection, conduction and radiation or volumetrically in situ by placing the wet material in microwave or radiofrequency electromagnetic fields (Mujumdar, 2007). Drying is energy-intensive process accounting for 10–25% of the total energy used in the food manufacturing process worldwide (Strumillo and Adamiec, 1996). Fruits and vegetables are usually dried to extend shelf-life, enhance storage stability, minimize packaging requirements and reduce transport weight. Numerous processing techniques have been used for dry drying of fruits and vegetables (Ahmed, 2011). Conventionally, fruits and vegetables are sun- or hot-air-dried. Traditional solar drying is often a slow process