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ScienceDirect
Journal of Food Engineering 80 (2007) 111–118
JOURNAL OF FOOD ENGINEERING
www.elsevier.com/locate/jfoodeng

Drying of cherry tomato by a combination of different dehydration techniques. Comparison of kinetics and other related properties

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Received 25 January 2006; received in revised form 26 April 2006; accepted 30 April 2006
Available online 11 July 2006

Abstract

Dehydration of tomatoes is a process commonly used to preserve the product and extend shelf-life. However, the quality of the dehydrated product is often poor. Collapse of the structure, discoloration and a tough texture are frequent quality problems. No less important, although not visually apparent, is the lack of flavour and nutritional value. The combination of osmotic dehydration and microwave drying is a potential new process that could improve the quality of dried tomatoes. In the present work, various osmotic solutions formulated with salt, sugar and calcium lactate were used in an osmotic treatment prior to microwave assisted air drying. The influence of microwave energy on the kinetics was analyzed and correlated with the dielectric properties of the samples. The results showed that osmotic dehydration with ternary solutions (27.5% sucrose, 10% salt and water (w/w)) with the addition of 2% of calcium lactate combined with microwave assisted air drying makes it possible to obtain dried and intermediate moisture tomato products that are shelf stable and have better quality than the traditional product.

Keywords: Tomato; Microwaves; Osmotic dehydration; Calcium lactate

1. Introduction

Cherry tomatoes (*Lycopersicon esculentum* var. Cerasiforme) are commercialised as a substitute for salad tomatoes in catering, but their introduction in processed forms has not yet been developed.

Solar drying is frequently used to process tomatoes but can produce an adverse effect on the quality of the final product. The fruit tissue darkens upon drying (Gupta & Nath, 1984), and a characteristic flavour is developed. Nevertheless, the interest in production of dried tomatoes is increasing both for the possibility of using them in different dishes and for their functionality.

High temperatures or long drying times in conventional air drying can cause serious damage to product flavour, colour and nutrients, and reduce the rehydration capacity of the dried product (Lin, Durance, & Scaman, 1998; Drouzas, Tsami, & Saravacos, 1999). The most common are pigment degradation, especially carotenoids like lycopene (responsible for the red colour in tomatoes) and chlorophyll, and browning reactions such as Maillard condensation of hexoses and amino components, and oxidation of ascorbic acid (Barreiro, Milano, & Sandoval, 1997). Other factors affecting colour include fruit pH, acidity, processing temperature and duration, fruit cultivar and heavy metal contamination (Abers & Wrolstad, 1979; Skrede, 1985).

Consumer demand has increased for processed products that keep more of their sensory properties and their nutritional value, so that it has become necessary to optimise drying conditions in order to achieve certain characteristics related to colour, texture, water content, etc.

Microwave energy can be successfully applied in several processes in the food industry because the resulting

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doi:10.1016/j.jfoodeng.2006.04.056

Notation

OD	osmotic dehydration
ε'	dielectric constant (dimensionless)
ε''	loss factor (dimensionless)
$\tan\delta$	loss tangent or dissipation factor (dimensionless)
D_p	penetration depth (mm)
ΔE	colour change (dimensionless)
L^*	lightness (CIELab tristimulus colour values)
a^*	redness (CIELab tristimulus colour values)
b^*	yellowness (CIELab tristimulus colour values)
M_t^o	sample weight at time t (g)
ΔM_t^i	net change of component i at time t (g component i/g initial)
x_t^i	mass fraction of component i at time t (g component i/g)
z_t^i	mass fraction of component i in liquid phase at time t (g component i/g liquid phase)
a_w	water activity (dimensionless)
k	kinetic constant in drying process (min^{-1})

Subscripts

0	initial values ($t = 0$)
t	values at time t

Superscripts

w	water
ss	soluble solids
NaCl	sodium chloride

volumetric heating of the material results in a slower transfer of heat from the surface to the interior of the fruit, compared to convective drying. This phenomenon is related to the energy converted into kinetic energy of water molecules and then into heat, when the water molecules realign in the changing electrical field and interact with the surrounding molecules (friction) (Khraisheh, Cooper, & Magee, 1997). Combining microwave and convection drying in fruits and vegetables has been reported to improve product quality in the form of better aroma, faster and better rehydration, considerable savings in energy and much shorter drying times, compared with hot air drying (Decareau, 1985; Maskan, 2000; Mudgett, 1989; Rosenberg & Boegl, 1987; Torringa, Van Dijk, & Bartels, 1996).

The dielectric properties of materials are of critical importance in understanding their capability to interact with microwave electromagnetic energy. These properties, along with thermal and other physical properties, and the characteristics of the microwave electromagnetic fields, determine the absorption of microwave energy and the consequent heating behaviour of food materials in microwave heating and processing applications (Nelson & Datta, 2001). Among the dielectric properties, the dielectric constant ε' and the dielectric loss factor ε'' are usually of interest. The loss tangent or dissipation factor ($\tan\delta = \varepsilon''/\varepsilon'$) is also used as a descriptive dielectric parameter, as well as the penetration depth (D_p), which is defined as the distance at which the power drops to 37% of its value at the surface of the material. The dielectric properties of most materials are affected by many different factors, but the amount of water is generally the dominant factor. They also depend on the frequency of the electric field applied, the temperature of the material and the material density, structure and chemical composition, especially on the presence of mobile ions.

The combination of osmotic dehydration (OD) with microwave–convective drying has been proposed for fruits and vegetables by many authors in order to reduce drying time and introduce into the product solutes such as sucrose, salt or calcium (Ertekin & Cakaloz, 1996; Kim & Toledo, 1987; Lerici, Mastrocolla, & Nicoli, 1988; Torreggiani, 1993). In addition, osmotic dehydration is effective at relatively low temperature with minimal damage to colour and texture.

Calcium is often used in the food industry to improve the rheological properties of a product as well as for technical reasons. Calcium preserves the cell wall structure in fruit and vegetables by interacting with the pectic acid in the cell walls to form calcium-pectate, which maintains the firmness of the product after different treatments (Lara, García, & Vedrell, 2004). Calcium not only has a major effect on cell wall structure and membrane integrity, but also plays a regulatory role in various processes that affect cell function. Extensive cross-linking with pectin polymers may restrict the access of hydrolytic enzymes to cell wall compounds, and therefore calcium has an indirect role in keeping the middle lamella intact (Ahrné, Prothon, & Funebo, 2003).

The aim of this study was to compare the drying kinetics of cherry tomato halves under different combinations of dehydration techniques, and their correlation with colour, texture and dielectric properties. The influence of the type of osmotic solution (brine or salt/sugar solution), the addition or absence of calcium lactate, and the microwave power applied were evaluated.

2. Materials and methods

2.1. Raw material

Fresh cherry tomatoes (*Lycopersicon esculentum* var. Cerasiforme cv. Cocktail), obtained from local markets, were sorted visually for colour (bright red), firmness, size (diameter 2.5–3.0 cm) and physical damage absence.