



Physical properties, morphology and saltiness of salt particles as affected by spray drying conditions and potassium chloride substitution

Nathamol Chindapan^a, Chalida Niamnuy^{b,*}, Sakamon Devahastin^c

^a Department of Food Technology, Faculty of Science, Siam University, 38 Phetkasem Road, Phasicharoen, Bangkok 10160, Thailand

^b Center of Advanced Studies in Industrial Technology, Department of Chemical Engineering, Faculty of Engineering, Kasetsart University, 50 Ngam Wong Wan Road, Chatuchak, Bangkok 10900, Thailand

^c Advanced Food Processing Research Laboratory, Department of Food Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, 126 Pracha u-tid Road, Tungkrui, Bangkok 10140, Thailand

ARTICLE INFO

Article history:

Received 23 May 2017

Received in revised form 24 August 2017

Accepted 1 December 2017

Available online 6 December 2017

Keywords:

Microstructure

Physical properties

Sensory evaluation

Spray drying

Surface characteristics

X-ray diffraction

ABSTRACT

Since excessive intake of sodium increases the risk of an array of diseases, much effort has been made to reduce sodium in food. Here, combined use of spray drying and KCl substitution to modify the physical properties and morphology of KCl/NaCl salt particles was attempted. The effects of inlet air temperature, feed flow rate and KCl substitution level on the moisture content, particle size, surface area, bulk density, hygroscopicity, crystallinity, morphology, N₂-sorption characteristics, crystallinity and saltiness of the salt particles were determined. Combined use of KCl and NaCl created surface irregularities and pore interiors of the salt particles. Although higher feed flow rate and KCl substitution level resulted in significantly larger particle size, salt particles with the highest KCl substitution level (30%) exhibited highest hygroscopicity and saltiness because of their lower bulk density and existence of agglomeration, surface roughness and macro pores. All spray-dried salt particles were noted to be crystal-like.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

It is well recognized that high intake of sodium is associated with the risk of hypertension, and consequently with the risk of other non-communicable diseases, including osteoporosis, cardiovascular diseases and stroke in humans [1]. World Health Organization (WHO) indeed recommends the dietary intake of sodium of lower than 2 g/day in adults (≥16 years old), which is equivalent to 5 g/day of salt [2]. However, the average intakes of salt are 12, 8.8, and 9.4 g/day in Asian countries, United States and United Kingdom, respectively [3]. Among the aforementioned intakes, much of sodium comes from the salt that is added to an array of snacks, including chips, crackers as well as dried and oil roasted nuts; salt is added to provide saltiness and act as a flavor enhancer to these snacks. In such cases, salt is consumed in a dried particulate form, without being dissolved in food.

Among the possible alternatives to reduce sodium in salty snacks, preparation of salt particles by partial substitution of sodium chloride (NaCl) with potassium chloride (KCl) is quite popular [4,5]. Although the saltiness of KCl is lower than that of NaCl, a mixture of both salts exhibits a similar level of saltiness to that of pure NaCl of equivalent mass [6]. However, the level of KCl substitution must be carefully considered as KCl can impart metallic flavor along with bitterness aftertaste. Several

works have reported that it is possible to substitute up to 30% of NaCl with KCl without the metallic-bitterness aftertaste and a noticeable loss of saltiness intensity [4–5,7–8].

The delivery of sodium to taste receptor cells is not only dependent on the diffusion of sodium ion through the static saliva barrier layer on the tongue surface, but also on the dissolution of salt particles [9]. Smaller-size salt particles with higher surface area as well as salt particles that have highly agglomerated structure with higher porosity therefore exhibit higher saltiness intensity due to their rapid dissolution upon consumption [9–10]. As a result, smaller-size salt particles are needed at a smaller amount when compared with conventional larger-size salt particles if a similar saltiness level is to be achieved. In fact, commercial extra fine NaCl or KCl/NaCl salts that are designed to be used in various applications are available, including Microsized® 95 Extra Fine Salt (Cargill Salt, Minneapolis, MN) and FlakeSelect® Potassium Chloride/Sea Salt (Cargill Salt, Minneapolis, MN); these salts have average diameters of 15 μm and 142 μm, respectively [11–12]. Nevertheless, it has been reported, based on the just-about-right scale method for sensory test, that a 1-log reduction in the particle size of Microsized® 95 Extra Fine Salt can further increase its saltiness [11]. Super small-size salt particles can be obtained either by mechanical grinding of larger salt crystals, anti-solvent crystallization or spray drying. However, particles obtained from grinding and anti-solvent crystallization may exhibit broad size distribution and asymmetric crystal morphology, which is undesirable [13–16].

* Corresponding author.

E-mail address: fengcdni@ku.ac.th (C. Niamnuy).

Spray drying is well known as a method that can be used to effectively produce particles of micro and nano sizes [15] and can well control the various particle properties, including the particle size, size distribution and morphology [17]. Morphology, especially the agglomerated structure of spray-dried particles, in turn exhibits a significant effect on the particle dispersability, wettability, sinkability and solubility [10,18–19]. In the case of salt, it has been reported that spray drying often results in a largely, but not completely, crystalline structure [13] and it is that slightly amorphous structure that can lead to a higher hygroscopicity, solubility and dissolution rate since such a structure possesses more surface area for water adsorption.

Some works do exist on the production and use in various food applications of spray-dried NaCl particles with/without sodium replacement. Moncada et al. [11], for example, reported that cheese crackers surfaced with nano spray-dried salt particles (1.5 µm in average particle size) had significantly higher just-about-right saltiness scores than the crackers surfaced with Microsized® 95 Extra Fine Salt (15 µm in average particle size) and regular salt (1500 µm in average particle size). Reduction in the NaCl salt particle size by 3 log from that of the regular salt reduced up to 25–50% of the salt requirement for the cheese crackers to be acceptable by the test panels. Chun et al. [20–21] who studied the effect of the use of spray-dried gamma-aminobutyric acid (GABA)/NaCl and monosodium glutamate (MSG)/NaCl on the sensorial properties and quality of meat products reported that the salts incorporated with both boosters had higher surface area and could enhance the salty flavor and overall acceptability of pork patties when compared with the salt with no boosters. It is therefore of interest to produce spray-dried salt particles with smaller size and larger surface area; partial substitution of NaCl with a salt replacer, in particular KCl, should also be attempted. However, detailed information on the effects of spray drying conditions and partial KCl substitution on the physical properties, morphology and saltiness intensity of spray-dried salt particles that would allow successful production of such particles is still lacking.

In this work, the effects of inlet air temperature, feed flow rate and KCl substitution level on various physical properties, namely, moisture content, particle size, surface area, bulk density, hygroscopicity, as well as morphology and saltiness of spray-dried salt particles were evaluated. X-ray diffraction analysis and N₂-sorption measurement were performed to observe the crystal pattern and pore structure to support and explain the measured properties of the salt particles.

2. Materials and methods

2.1. Spray drying of KCl/NaCl mixture

An aqueous solution (25% w/v) of food-grade KCl and NaCl (Lab Systems, Bangkok, Thailand) at various KCl levels (0, 15 or 30% of the total salt concentration) was prepared by dissolving both KCl and NaCl in distilled water and stirring using a magnetic stirrer at 300 rpm for 20 min. Then, the solution was spray dried using a spray dryer (Buchi, B-290, Flawil, Switzerland) at different inlet air temperatures (140 and 180 °C) and feed flow rates (3 and 9 mL/min). All spray drying experiments were performed in duplicate. The various properties of spray-dried samples were compared to those of commercially available NaCl salt particles (Prung Thip, Bangkok, Thailand). The experimental conditions are listed in Table 1.

2.2. Moisture content determination

The moisture content of a spray-dried sample was determined using AOAC method 984.25 [22]. About 5 g of the sample were dried at 105 °C until no change in mass was detected.

Table 1
Experimental conditions.

Inlet air temperature (°C)	KCl substitution level (%)	Feed flow rate (mL/min)	Sample code
140	0	3	140T-0KCl-3f
140	0	9	140T-0KCl-9f
140	15	3	140T-15KCl-3f
140	15	9	140T-15KCl-9f
140	30	3	140T-30KCl-3f
140	30	9	140T-30KCl-9f
180	0	3	180T-0KCl-3f
180	0	9	180T-0KCl-9f
180	15	3	180T-15KCl-3f
180	15	9	180T-15KCl-9f
180	30	3	180T-30KCl-3f
180	30	9	180T-30KCl-9f
180	100	3	180T-100KCl-3f

2.3. Particle size and surface area determination

Particle size of a spray-dried sample was determined using a laser particle size analyzer (Malvern, Mastersizer S, Worcestershire, UK) with a wet analysis system at a beam length of 2.40 mm and an obscuration of 2.6%. Liquid paraffin was used as the disperse medium. Sauter mean (volume/surface mean) diameter ($D[3,2]$) of the sample is reported. The surface area was calculated with the assumption that the particles were spherical in shape; the following equation was used:

$$\text{Surface area (m}^2\text{/g)} = N \times \pi \times (D[3,2])^2 \quad (1)$$

where N is the number of salt particles per g sample and ($D[3,2]$) is the Sauter mean diameter of the sample.

2.4. Bulk density determination

Bulk density of a spray-dried sample was determined according to the method of Lavoie et al. [23], which follows the method described in the United States Pharmacopeia U.S.P. XXIV, Method (616). A 100-mL glass cylinder was weighed, then filled with 40 mL of salt particles and reweighed. The open extremity was secured with a parafilm (Pechiney Plastic Packaging, Neenah, WI). The cylinder was gently reversed and redressed once; the salt particles were carefully levelled without being compacted. The bulk density was then calculated by dividing the mass of the salt sample by the read total volume.

2.5. Hygroscopicity determination

Hygroscopicity of a spray-dried sample was determined according to the method of Goula and Adamopoulos [24] with some modification. About 0.5 g of the sample was weighed and spread in a glass vial (2.5 cm in diameter) and stored in a hermetically sealed plastic container, which was equilibrated over a saturated sodium chloride solution (relative humidity of 75.3%) at 30 ± 1 °C for 72 h. The sample mass was recorded at every 2 h for the first 10 h and then every 24 h. The hygroscopicity of the sample was determined as per the following equation:

$$\text{Hygroscopicity (g water/solids)} = \frac{M_t - M_o}{M_o} \quad (2)$$

where M_t is the mass of the humidified sample at any time (g) and M_o is the mass of the dried sample before moisture preconditioning (g).

2.6. X-ray diffraction (XRD) analysis

XRD pattern of a spray-dried sample was examined according to the method of Peng et al. [25] with some modification. The sample was

Download English Version:

<https://daneshyari.com/en/article/6675620>

Download Persian Version:

<https://daneshyari.com/article/6675620>

[Daneshyari.com](https://daneshyari.com)