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Relation of moisture distribution and texture of rice-based foods – a perspective

Widjajaseputra, A.I.

Department of Food Technology, Faculty of Agricultural Technology, Widya Mandala Surabaya Catholic University Surabaya,, Jalan Dinoyo 42-44 Surabaya 60625, Indonesia

Abstract: Study of moisture distribution of starch-based food especially in rice-based raw material during processing is a major technological challenge. Homogeneity of moisture distribution influenced certain physical properties of food product such as the elongation at break of the spring roll wrappers, crispness of fried snack and the mouth feel of bread. Moisture distribution of foods product was determined by moisture migration process which was influenced by holding time or tempering time, raw material composition, heating temperature, level of amylose in rice and others. Homogeneity of moisture distribution of rice-based food product was influenced by natural character of rice itself. Though rice is lacking in appropriate amount of hydrophobic gluten- forming proteins, the glutelin and albumin in rice can form gel. Water migration influenced moisture distribution because it determined water transport mechanism which is further enhanced by the complexity of food structure and its composition.

Key words: Moisture distribution, texture, rice-based

Introduction

Moisture distribution of foods product is determined by raw material composition, heating temperature, moisture migration process which is influenced by holding time or tempering time, level of amylose in rice and others. Rice flour has different characteristics compared to wheat flour, thus requiring modification in its formula and processing conditions. Rice flour will form higher amount of free water in the batter system due to the sizes of the starch granules (3-8 microns) and its inability to form gluten. Rice contains hydrophobic gluten-forming proteins such as prolamin (2 – 7%) and glutelin (77 – 78%) (Liang and King, 2003). Though these proteins are hydrophobic, glutelin and albumin can form gel (Yang and Xu, 2007) and contribute to its lower water holding capacity when compared to wheat flour. In some cases tapioca is added to the formulation to strengthen the gel structure of the starch, increasing it's cohesiveness and producing a non-sticky product (Larotonda *et al*., 2004).

Water migration

Water migration in food products is the consequence of a number of coexisting moisture transport mechanisms, enhanced by the complexity of the food structure (e.g. porosity) and interaction of water with other food constituents (Roca *et al*., 2006). Water vapor evaporation and water migration occurred through the system during cooling process (World Intellectual Property Organization, 2008). This change resulted in a drop of temperature and resulting in products that are in rubbery and glassy state (Moraru and Kokini, 2003). These conditions make the products more cohesive and are removed from the frying-pan easily.

In starch-based food processing, immediately after cooking, heating or frying, a tempering or holding time is required to get stable products. A temperature gradient exists within the product; the temperature of the outer layer is noticeably lower than the internal region. As a consequence, vapor pressure varies noticeably between the outer part and the internal part, promoting moisture migration from the higher moisture content part. Besides the internal moisture transport, during the cooling stage, part of the moisture migrates from the outer to the surrounding atmosphere. During this tempering process, stabilization of gelatinized starch gel matrix and water evaporation will produce a solid material. The material is an inter-connected polymer chain, providing it with a considerable tensile strength (Andersen *et al*., 2000). This process determined the amount of trapped water in the product that will affect the speed of retrogradation and product

*Corresponding author.
Email: *ingani9456@yahoo.com*

characteristics, such as elasticity, cohesiveness and density (Nunes *et al*., 2006). Short tempering time will produce a sticky product which is related to high amount of surface water as a result of insufficient water migration from the surface to interior parts of the product. In contrary, long tempering time will dehydrate the product. Longer time of tempering may increase the alignment of free amylose molecules and starch crystallization which lead to decrease of water binding ability of the system, resulting in increasing of free water molecules and thus increasing the Aw (Yao *et al*., 2003).

Rice flour as a component of MiGao influenced the shelf stability which has been reported to be about 3 days and is shorter than wheat bread (Ji Zhu *et al*., 2006). It has been reported that gluten present in wheat bread slowed down the movement of water by forming an extensible protein network, thus keeping the crumb structure together (Ji Zhu *et al*., 2006). The absence of gluten formation should increase the movement of water from inner parts to outer parts which produced firmer product. The loss of water caused rigid crumb structure along with starch retrogradation and moisture redistribution.

Moisture distribution

Moisture distribution in partially-cooked and partially-fried foods has also influenced cracking and breaking of final products. Typically the dough has moisture content from about 10 wt-% to about 20 wt-% after frying. As a result of frying, the surface of the dough attains a bubbled texture. Bubble formation is caused by increasing vapor pressure in the dough and the escape of water from the dough when the dough is fried. Traditionally, the extent of bubble formation was thought to be important to achieve a tender texture, with a higher degree of bubble formation (covering more than 60% of the surface area) required for a more tender product (Thomas and Levin, 2001).

Moisture content and its internal distribution in cooked spaghetti is the primary factor affecting texture. One key factor contributing to the texture of pasta and noodles is the moisture distribution within the starch-protein network (Irie *et al*., 2004). Irie *et al*. (2004) studied moisture distributions in fresh, dried, frozen, luncheon and long-life spaghetti cooked under optimized conditions. Although consumers wish to have precooked or cooked spaghetti with texture similar to that of freshly cooked spaghetti, but the texture of product deteriorates very rapidly after cooking and during distribution to stores. This deterioration of texture is considered to be caused by the homogenization of moisture distribution. The diffusion coefficients of dried spaghetti were smaller than those of fresh spaghetti during both boiling and holding periods. The slower moisture diffusion in the dried spaghetti seemed to be due to the tighter structure formed in the drying process of the pasta (McCarthy *et al*., 1994). The rate of moisture transfer in the cooked spaghetti is proportional to diffusion coefficient and moisture gradient. Water migrates from the surface to the center, resulting in uniform water distribution, which was observed as the spreading of the region with a 60–65% moisture content. However, moisture content at the intersection of spaghetti sample boiled for 10 minutes was higher than the average moisture content due to the presence of an ungelatinized core where water diffusion is different from that in the gelatinized part (Horigane *et al*., 2006). Similar phenomena were also observed on fresh spring roll wrapper which was heated at 72^{o}C for 4 minutes and the relatively highest water content is at the center part of product (Widjajaseputra, 2010a).

Relationship between texture and water activity

Based on natural characteristics of rice such as lacking in gluten-former proteins, small size of starch granules and the ability to form homogeneous batter, rice-based formula needs hydrophilic materials like cassava flour to improve the cooking quality. The addition of cassava flour contributed to the crispy characteristics of the final products. Crispness of the baked samples was determined using a sensory approach. Fresh samples were highly crispy, with a score of 7.8, and were very moisture-sensitive. These specific values of water activity and moisture content (0.54 or 6%) could be considered as critical points of crispness loss (Kulchan *et al.*, 2010). These critical water activity values corresponded to those of other dry crisp starch–protein-matrix products, reported as approximately 0.5 (Roos *et al*., 1998; Kulchan *et al.*, 2010). This matrix was significantly softened by the plasticization effect of adsorbed water above the critical level (Martinez-Navarrete *et al.*, 2004). The change of texture was affected by molecular mobility which is facilitated by adsorbed moisture from the environment. The moisture adsorption rate was determined by the barrier property of the packaging material, as well as the storage condition. However, Roca *et al.* (2006) reported that shelf-life of a moisture-sensitive food product is affected not merely by moisture adsorption but also by moisture migration in the food product, which is greatly affected by the complexity of the food structure.

Table 1.Moisture distribution (%) per segment of rice-based spring roll wrappers

Segment of spring roll wrapper	Amylose Content (%)					
	25	28	31	34	37	40
1	33,08 ab	38,23 bc	28,82 ab	40,24 a	46,40 cd	45,97 ef
2	29,02 a	33,72 ab	40,06 cd	33,65 a	43,78 bcd	37,69 bcd
3	32,33 ab	30,52 a	45,23 cd	40,43 a	32,68 ab	30,83 a
4	34,50 b	30,05 a	50,49 d	50,00 b	43,51 bcd	47,34 ef
5	40,98 c	42,72 c	38,66 bc	41,59 a	35,78 abc	37,58 bc
6	41,66 cd	36,45 b	51,12 d	37,47 a	50,10 d	48,01 ef
7	30,73 ab	40,10 c	37,02 bc	37,19 a	48,27 d	42,92 cde
8	43,02 cd	39,64 c	19,84 a	34,66 a	27,98 a	34,66 ab
9	43,40 d	41,49 c	50,62 d	49,95 b	49,24 d	50,01 f

*Different notations on the same column indicated significantly difference on α = 5%
Each segment was obtained by cutting the original sample in accordance to 4 cardinal and 4 inter cardinal directions. The ninth segment is the centre of sample.

Source: Widjajaseputra, 2010a

Table 2. Elongation at break of fresh rice flour-based spring roll wrappers

Amylose Content (%)	Elongation at Break *)
25	16.07 e
28	14.52 d
31	14.27 cd
34	13.71 c
37	12.03 b
40	10.96 a

*Different notations on the same column indicated significantly difference on α = 5%

Source: Widjajaseputra et al., 2010b

Role of amylose content on the moisture content and moisture distribution of fresh rice flour-based spring roll wrappers

The levels of amylose contributed to the homogeneity of moisture distribution on the heating temperature of 72°C for 4 minutes of fresh rice flour-based spring roll wrappers (Table 1). Amylose levels of 34% produced products with a relatively homogeneous distribution of water with average water content of 40.58%. Hence, increasing of amylose content resulted in moisture content increased, and this is related to the amylose function as gel former, in which amylose molecules are aligned by hydrogen bonds and release water molecules (Dogan, 2004). This phenomenon can also explain the occurrence of interactions between starch and protein by increasing levels of amylose. Increasing free amylose strengthen starch-protein matrix and formed gel system which will be able to trap more water.

Homogeneity of distribution of water can occur due to the achievement of equilibrium between the trapping of water in the formed gel system and the water migration process both internally within the system as well as with its surroundings. This condition has limited the water mobility and provided more optimal hydration process (Widjajaseputra, 2010a). The varied moisture distribution in starch-based foods was caused by partially gelatinized starch and the difference in their ability of gel formation. The phenomena reflected various levels of protein-protein interactions and the number of available interactive side between the molecules during the heating process (Alleoni, 2006).

Table 2 showed that an increase of amylose content tends to decrease elongation at break. Increasing entrapped water decreased cohesiveness and affected elongation at break.

This characteristic determined the flexibility of spring roll wrapper. In this condition water in the system acted as a plasticizer materials (Chang *et a*l., 2006)

Conclusions

Based on the characteristics of some of the rice-based foods, it can be concluded that homogeneity of the moisture distribution determines the foods texture. By controlling the moisture distribution and the related factors should reduce the percentage of rejected products in many kinds of food manufacturing such as fried and cooked rice-based products, spring roll wrappers and noodles.

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