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Physicochemical properties and starch digestibility of Chinese noodles in relation to optimal cooking time

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ABSTRACT

Changes in the physicochemical properties and starch digestibility of white salted noodles (WSN) at different cooking stage were investigated. The noodles were dried in fresh air and then cooked for 2–12 min by boiling in distilled water to determine the properties of cooking quality, textural properties and optical characteristic. For starch digestibility, dry noodles were milled and sieved into various particle size classes ranging from 0.5 mm to 5.0 mm, and hydrolyzed by porcine pancreatic α-amylase. The optimal cooking time of WSN determined by squeezing between glasses was 6 min. The results showed that the kinetics of solvation of starch and protein molecules were responsible for changes of the physicochemical properties of WSN during cooking. The susceptibility of starch to α-amylase was influenced by the cooking time, particle size and enzyme treatment. The greater value of rapidly digestible starch (RDS) and lower value of slowly digestible starch (SDS) and resistant starch (RS) were reached at the optimal cooking stage ranging between 63.14–71.97%, 2.47–10.74% and 23.94–26.88%, respectively, indicating the susceptibility on hydrolysis by enzyme was important in defining the cooked stage. The study suggested that cooking quality and digestibility were not correlated but the texture greatly controls the digestibility of the noodles.

1. Introduction

Noodles have been consumed as staple foods for more than 4000 years, especially in Asian countries [1]. Among the several available varieties, white salted noodles (WSN) have the desirable eating qualities such as taste, color and texture [2]. WSNs are prepared in various formulations and shapes, and the dough is a mixture of wheat flour, water and salt. The wheat flour is mainly composed of two biopolymers starch and gluten protein. The dough texture is due to the continuous three-dimensional network structure as result of the gluten adherence to the starch granules, and even prevails in the noodles thus prepared. Changes in the structure transformations are often found in noodle products with compact matrix form during cooking. The heat-induced alterations are mainly influenced by the kinetics of solvation of starch and protein, which in-turn modify the starch-protein interactions and the microstructure [3]. Thus, changes in the cooking process impact the overall digestibility of noodles.

The enzymes necessary to digest the starch are possessed by most of the non-carnivorous mammals. The principal enzyme α-amylase, active at about pH 6.5 in the mouth and at about pH 7.5–8.0 in the small intestine of healthy humans, has evolved so many times in different organisms and could be the 'record holder' in the molecular convergent evolution [4]. The suggested sources of digestive improvement in humans compared to related mammals are both genetic and cultural. The cooking process gelatinizes the starch granules, particularly in high-moisture environments, and modifies the starch digestion [5]. In the archaeological record, starch granules have only been recovered from the sites less than 100,000 years old, and the ancient cooking could most likely have involved roasting. Thus, there is little evidence for the efficacy of dry heat in improving the starch digestibility (*e.g.* cereal product) compared to the high-moisture environment.

A study on noodles might be thought to be trivial for understanding why humans have so much salivary α-amylase. The earliest solid evidence of an actual cooked food appears to be the noodle, recorded around 4000 years BCE from the Chinese late Neolithic period [1]. The current research is simply a model study of showing that the action of α-amylase could be rapid on the cooked and air-dried noodles. Though noodles are made from grains, not the underground storage organs (possibly) loved by early humans,

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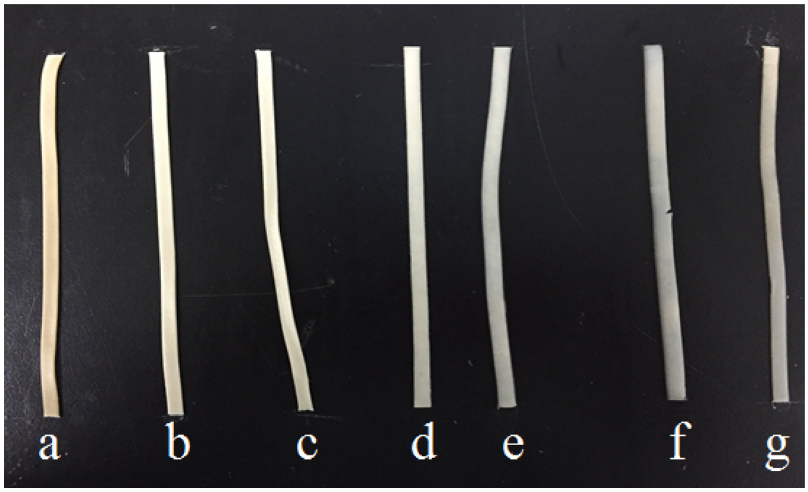

Fig. 1. Effect of cooking time on the appearance of white salted noodles. (a) Raw noodle. (b)Cooked white salted noodles for 2 min. (c) Cooked white salted noodles for 4 min. (d) Cooked white salted noodles for 6 min. (e) Cooked white salted noodles for 8 min. (f) Cooked white salted noodles for 10 min. (g) Cooked white salted noodles for 12 min.

boiled noodles and pasta are arguably among the most popular starch-rich foods in the world. Thus, they represent a reasonable choice of a model food system in an investigation of the definition of the cooked state.

Starch could be divided into three categories based on the digestion rate: rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) [7]. All but the RDS could be acted on rather or somewhat easily by the α-amylase and subsequently by the maltooligosaccharidases, starting in the mouth and ending with the liberation of D-glucose in the small intestine. RDS is completely converted into glucose (in the small intestine) within 20 min, but do not indicate the physical conditions involved [6]. Entire SDS is also digested in the small intestine, but at a slower rate as it consists of physically inaccessible amorphous starch. RS as a fraction of starch resists the hydrolysis by the α-amylase and pullulanase [7]. There are reported health benefits for RS ingestion [8]. It is, therefore, interesting to examine the factors that affect the rate of digestion of starchy foods.

The earlier studies have mainly examined the genetic resources of crops and chemical additives on the physicochemical properties of noodles [1], but not the role of cooking time. In this regard, the main objective of this research is to understand the cooking induced changes, mainly the physicochemical properties and starch digestibility, and WSN have been chosen as the model system.

2. Material and methods

2.1. Materials

Commercial wheat flour (‘Red Bicycle’) was obtained from Hong Kong Flour Mills (Kowloon, Hong Kong). Amyloglucosidase, pancreatin from porcine pancreas and guar gum were purchased from Sigma Chemical Co. (St. Louis, MO, USA). Glucose assay reagents were purchased from Megazyme International Ireland Ltd. (Wicklow, Ireland).

2.2. White salted noodles (WSN) preparation

The preparation is based on our earlier protocol with minor modifications [9]. The wheat flour (25 g, 14% moisture basis) was mixed with 8.5 g of NaCl solution (2%, w/w) thoroughly. It was then manually kneaded in a bowl to obtain a homogeneous dough ball. After resting in a sealed plastic bag for 30 min, the dough was sheeted through the rolls of a domestic-type pasta machine (Atlas Electric Model 150, Marcato Co., Italy) seven times at reduced gap settings (from 2.5 mm to 0.4 mm) and finally passed through a slitter to produce fresh noodles of 6.6 mm in width. They were dried at the room temperature (25 °C) to a constant weight, around 24 h, on an aluminum rectangular tray.

2.3. Cooking procedure

The dried noodles (5 g, dry base) were cooked in a beaker by boiling in 300 mL of distilled water for 2–12 min at 2-min intervals. Subsequently, they were cooled with distilled water at room temperature (25 °C) for 30 s. Dried noodles in their native state are referred as WSN0, and WSN2, WSN4, WSN6, WSN8, WSN10, WSN12 represent cooked WSN for 2, 4, 6, 8, 10, 12 min, respectively.

2.4. Optimal cooking time

The optimal cooking time of WSN was determined according to the method described by Hormdok and Noomborm [10]. Briefly, dried noodles (5 g) were cut into 6 cm lengths and cooked in 300 mL of boiling distilled water. Samples were squeezed between two glass plates and the time needed for the disappearance of the white core of WSN was measured.

2.5. Cooking quality

The cooking quality of was evaluated by following the previously described procedure with minor modifications [11]. Dried noodles (5 g) were cooked and transferred to the paper towel and left to stand for 1 min to remove the excess water. The remaining water in the beaker was heated in a hot air oven at 140 °C to a constant weight. The percentage of cooking yield (CY) and cooking loss (CL) were calculated using the following equations.

$$CY = \frac{Mco \times 100}{Md}$$

where Mco is the weight of cooked noodles (g); Md is the weight of dried noodles (g).

$$CL\,(\%) = \frac{(Mc - Mb) \times 100}{Md - Mm}$$

where Mb is the weight of beaker (g); Mm is the weight of moisture in dried noodles.