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Effect of matrix and particle type on rheological, textural and structural properties of broccoli pasta and noodles

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ABSTRACT

Durum wheat semolina (DWS) pasta and sweet potato starch (SPS) noodles were incorporated with different volume fractions and types of broccoli powder (up to 20% v/v). The incorporation of high volume fractions of broccoli powder produced in-house in SPS noodles increases the modulus of the dough and the stiffness and strength of the noodles as these broccoli particles can swell to up to 7.6 times their original volume. This effect is smaller when commercially available broccoli powder is used, as this powder can only swell 2.6 times. These results are confirmed by CLSM images. The incorporation of the two types of broccoli powder in DWS shows little effect on the rheology of this system. Since there is no difference between the water binding capacity of SPS and DWS, the small effects on rheology observed in the DWS system are due to the strong gluten network that can prevent the broccoli particles from swelling.

1. Introduction

In the current lifestyle, with increasing numbers of obesity, the demand for new food products that have some additional health benefits is increasing rapidly (Ritthiruangdej et al., 2011). Both durum wheat semolina (DWS) pasta and starch noodles are very popular foods around the world and are considered healthy and an ideal food to be enriched with nutrients (Chillo et al., 2008; Izydorczyk et al., 2005; Wang et al., 2012). Pasta has a low fat content, contains no cholesterol and has a low glycemic index (Fares and Menga, 2012). Similar to pasta, starch noodles also have a low glycemic index, and are referred to as a source of resistant starch. Resistant starch is unavailable for digestion and therefore can be a possible solution to fight obesity (Keenan et al., 2006). The enrichment of pasta and noodle products by nutrients will therefore be valuable for dietary benefits. Several studies have already reported successful (protein) enrichment of DWS pasta, especially with a variety of flours from peas and beans, such as pigeon pea (Torres et al., 2006), soy (Baiano et al., 2011), common bean (Gallegos-Infante et al., 2010), lupin (Torres et al., 2007), corn germ (Lucisano et al., 1984), chickpea (Wood, 2009), faba bean and split pea (Petitot et al., 2010). Besides beans, also dried green leaves such as spinach and amaranth have been incorporated (Borneo and Aguirre, 2008). Although a lot of examples can be found for DWS, enrichment of sweet potato starch (SPS) noodles is not a common practice. There are only a few studies available that describe the enrichment of SPS noodles (Krishnan et al., 2012; Limroongreungrat and Huang, 2007; Silva et al., 2013). A possible explanation for the preference of fortification of DWS systems instead of SPS might be related to the most significant difference between these two materials, which is the presence of gluten in DWS (Tan et al., 2009). High quality pasta is obtained because of gluten (Dexter and Matsuo, 1978). This protein provides a certain viscosity, elasticity and cohesiveness to the dough and contributes to the water holding capacity of the cooked pasta (Wieser, 2007). In starch systems, a possible solution to compensate for the lack of gluten is to pre-gelatinize part of the starch, which will act as a binder between the starch particles (Chillo et al., 2009). In previous work, we have investigated the effect of loading high volume fractions of broccoli particles into a SPS matrix. The results show that adding high volume fractions (>10% dry volume) has negative effects on the quality of these products. We have showed that this effect was caused by the swelling of the broccoli particles, thereby increasing the effective volume fraction to such extend that the amylose matrix was interrupted (Silva et al., 2012). One way to overcome that problem is to use hydrocolloids with a high water binding capacity, such as xanthan gum to limit the swelling of

Abbreviations: DWS, durum wheat semolina; SPS, sweet potato starch; PGS, pre-gelatinized starch; BP, broccoli powder; CBP, commercial broccoli powder; HMBP, broccoli powder produced in-house; BPulp, Broccoli pulp.

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the particles (Silva et al., 2013). Water diffusion and water holding capacity are therefore essential parameters that influence the quality of pasta and starch products. Both DWS and SPS are known to be able to bind water up to twice their own weight (Sozer, 2009; Tian et al., 1991). However, the gluten present in DWS forms a very strong network, whereas starch cannot form a network and acts only as a binder between the starch granules (Bache and Donald, 1998; Fu, 2008). As a result, we expect that using SPS or DWS with high loadings of broccoli will have different effects on the structure and quality of these products. Therefore, in this work we have studied the effect of the incorporation of different types and concentrations of broccoli particles on the structure of these different matrices (DWS and SPS). The broccoli particles differ in swelling behavior and are added either in a dry or wet state. This induces different water migration and network formation of the filled pasta and noodle products, leading to different properties of the dough and the cooked pasta/noodles.

2. Materials and methods

2.1. Materials

Sweet potato starch (SPS) (Mong Lee Shang) was kindly supplied by Deximport (Barendrecht, The Netherlands) and durum wheat semolina (DWS) was purchased at a local windmill (De Vlijt, Wageningen). Broccoli was bought in a local supermarket (Spar, Wageningen, The Netherlands) and the commercial broccoli powder (CBP) was purchased from Z Natural Foods, LLC (West Palm Beach, USA). Deionized water was used to prepare all samples.

2.2. Water binding capacity (WBC)

The water binding capacity of the SPS and the DWS was measured according to the method used by Medcalf and Gilles (1965) with minor changes. Briefly, 2.57 (±0.12) g of sample (pre-gelatinized SPS or DWS) were added to 35 ml of water and centrifuged at 16,040*g* for 1 h. The supernatant was removed and the pellet was drained for 10 min and weighed.

2.3. Broccoli powder and pulp preparation

The broccoli powder was produced in-house (HMBP) for which the method is described elsewhere (Silva et al., 2012). Both HMBP and CBP had a particle size distribution between 25 and 53 μm. Broccoli pulp (BPulp) was prepared from fresh cut broccoli florets frozen in liquid nitrogen and immediately blended in a kitchen machine ("Thermomix" Vorwerk, The Netherlands). The BPulp was not sieved and was used as is.

2.4. Swelling behavior of broccoli particles

The swelling behavior of the dried broccoli powder (BP) was determined using capillary viscometry (Ubbelohde), following the method described by Silva et al. (2012). A suspension of dried broccoli particles was used to prepare a series of dilutions with volume fractions between 0.02% and 0.4%.

2.5. Sweet potato starch/broccoli-sweet potato starch dough/noodles preparation

The preparation of the SPS dough and the SPS dough with broccoli incorporated followed the same method used in our previous study (Silva et al., 2012). In the present study, the pre-gelatinized starch was always set at 10% and the ratio starch:water for the pre-gelatinization of starch was 1:9. Moisture content was always set at 55% (v/v). The starch to be pre-gelatinized was mixed with the appropriate amount of water and placed in a water-bath at 100 °C. The solution was stirred until it became translucent (approximately 1 min after stirring and observed visually). After this step, the solution containing the pre-gelatinized starch was moved to a water-bath set at 40 °C. To this mixture, the remainder of the starch and water was added. Stirring was continued until a uniform dough was obtained (approximately 6 min). Samples with 4%, 10% and 20% BP were produced and the BP concentrations always refer to v/v. For broccoli containing doughs, part of the starch was replaced by broccoli powder and was added after a blank uniform dough was obtained. The dough was stirred for 1 more minute to evenly disperse the broccoli powder. The doughs were then transferred to 5 ml syringes (Plastipak, Italy) of which the tip of the syringe was removed. The noodles were produced by pressing the plunger of the syringes at a controlled rate and the created noodles were collected in cooking water. The noodles with 4% and 10% BP were cooked for an optimal cooking time of 30 sec and the noodles with 20% BP for 1 min. After that, the noodles were rinsed with cold water, drained and analyzed within 20 min. The cooked noodles had an average cross-sectional area of 10.0 ± 1.4 mm^2.

2.6. Durum wheat semolina/broccoli-durum wheat semolina dough/pasta preparation

The DWS dough with and without (blank) broccoli was prepared by mixing the dry ingredients with water (35% v/v) and kneading by hand for 4 min for the doughs with 4% and 10% BP, and 5 min for the dough with 20% BP. After that, the dough was passed 5–7 times through a commercial sheeting/cutting machine to ensure homogeneous mixing, and the pasta strands were cooked in boiling water. The blank strands were cooked for 8 min and the strands with 4%, 10% and 20% BP were cooked for 8, 7 and 5 min, respectively. After that, the strands were rinsed with cold water and drained, and analyzed within 20 min. The cooked strands had an average cross-sectional area of 10.2 ± 0.8 mm^2.

2.7. Optimal cooking time

The optimal cooking time for the SPS noodles and the DWS pasta was determined according to Collado et al. (2001).

2.8. Shear rheology of dough

Shear rheology experiments were performed as described elsewhere (Silva et al., 2013). The rheological measurements were expressed in terms of complex modulus since we were interested in the comparison between the different samples. Besides that, the low values for the loss tangent (<0.26) indicated that the loss modulus is not relevant in these samples and the behavior is dominated by the storage modulus.

2.9. Confocal laser scanning microscopy of dough and cooked noodles/pasta

Both dough and cooked noodles/pasta were analyzed by confocal laser scanning microscopy (CLSM). The samples were prepared as described before (Sections 2.5 and 2.6, for SPS dough/noodles, and DWS dough/pasta, respectively), and post-stained with a solution of 0.25% (w/w) Fluorescein 5-isothiocyanate (FITC) and 0.025% Rhodamin B in water. The image acquisition was done according to the method described by Silva et al. (2013).