LWT - Food Science and Technology 64 (2015) 1047–1056

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Physical and sensory characteristics of corn-based extruded snacks containing amaranth, quinoa and kañiwa flour

Jose Martin Ramos Diaz [a, *], Jussi-Petteri Suuronen [b], Kevin C. Deegan [a, c], Ritva Serimaa [b], Hely Tuorila [a], Kirsi Jouppila [a]

[a] Department of Food and Environmental Sciences, P.O. Box 66 (Agnes Sjöbergin katu 2), FI-00014, University of Helsinki, Finland
[b] Department of Physics, P.O. Box 64 (Gustaf Hällströmin katu 2), FI-00014, University of Helsinki, Finland
[c] Valio Research & Development, FI-00039 Valio, Finland

ARTICLE INFO

Article history:
Received 13 January 2015
Received in revised form
4 July 2015
Accepted 8 July 2015
Available online 11 July 2015

Keywords:
Amaranth
Quinoa
Kañiwa
Extrusion
Sensory attributes

ABSTRACT

Amaranth, quinoa and kañiwa are the most consumed Andean grains in Latin America, and possess high nutritional value as gluten-free substitutes for conventional cereals. The aim of this research was to examine the impact of these Andean grains on the sensory and physical properties of corn-based extruded snacks. Extrudates containing increasing contents of amaranth, quinoa or kañiwa (20, 35 and 50% of solids) were prepared under the same extrusion conditions. Extrudates with higher contents of amaranth, quinoa and kañiwa were rated less crispy, less crunchy and less adhesive with less hard particles. Temporal analysis showed that with increasing contents of amaranth, quinoa and kañiwa, crispiness and crunchiness were the most dominant attributes during mastication while the dominance of roughness reduced considerably. Porosity and wall thickness, measured by X-ray microtomography, were linked to the perception of crispiness and crunchiness, respectively. Despite the observable changes in the physical and sensory characteristics of extruded corn-based snacks, the incorporation of amaranth, quinoa and, particularly, kañiwa (the least studied Andean grain) showed promising results for the development of novel gluten-free products.

1. Introduction

The quest for naturally-grown alternative grains that present a good nutritional profile and adaptability to adverse weather conditions has increased in importance over the last years. Amaranth (*Amaranthus caudatus*), quinoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*) are originally from the Andes of South America where they have remained a staple since Pre-Hispanic times. Due to their protein quality (comparable to casein; Ranhotra, Gelroth, Glaser, Lorenz, & Johnson, 1993) and high content of fibre and bioactive compounds (Repo-Carrasco, 2011), these gluten-free grains are formidable food alternatives for celiac patients and/or those suffering from gluten-sensitivity. There is also an increasing demand for functional foods with bioactive compounds in the developed world (Grunert & Bech-Larsen, 2003; Williams, Pehu, & Ragasa, 2006). Several epidemiological studies on plant-based diets indicate protective effects against cardiovascular diseases and cancer (Kris-Etherton et al., 2002) when compared to the overconsumption of processed meat (Micha, Wallace, & Mozaffarian, 2010; Thorogood, Mann, Appleby, & McPherson, 1994). The increasing demand for healthier snacks goes hand-in-hand with the daily snack frequency (43% of US respondents snack three or four times/day in 2012 compared to 24% in 2009) and growth of organic snack sales (by around 11% in 2010 and 2011; SymphonyIRIGroup, 2012).

Extrusion cooking is a versatile and low-cost technology used for the production of cereal-based snacks. Extrusion transforms starch- and protein-based solid materials into a viscoelastic fluid under high pressure and temperature conditions. A drop of pressure at the die point vaporizes the water embedded in the fluid, leading to the formation of pores and an increase of sectional expansion. The content and type of fibre present in the flours may determine physical (sectional expansion, porosity, wall thickness etc.) and sensory (crispiness, crunchiness, hardness etc.)

Abbreviations: SEI, sectional expansion index; WAI, water absorption index; WSI, water solubility index.

* Corresponding author. P.O. Box 66 (Agnes Sjöbergin katu 2), FI-00014, University of Helsinki, Finland.
E-mail address: jose.ramosdiaz@helsinki.fi (J.M. Ramos Diaz).

http://dx.doi.org/10.1016/j.lwt.2015.07.011
0023-6438/

characteristics of extruded snacks. For instance, Yanniotis, Petraki, and Soumpasi (2007) prepared different starch-based extrudates with various contents of wheat fibre (insoluble) and pectin (0, 5 and 10% of solids). Increasing the content of wheat fibre reduced the sectional expansion and porosity of extrudates, thereby increasing hardness. Besides, the addition of pectin led to a slight reduction of sectional expansion and hardness, and an increase of porosity. This agrees with the results obtained by Brennan, Monro, and Brennan (2008) in which ingredients rich in dietary fibre were added to a wheat-based mixture (5, 10 and 15% of solids). The addition of wheat bran led to lower sectional expansion and higher moisture loss, density and hardness of extrudates, while inulin and guar gum had minor effects. Liu, Hsieh, Heymann, and Huff (2000) studied the effects of various contents of wholegrain oat flour on the physical and sensory properties of corn-based extruded snacks. The results showed a proportional correlation between the content of oat and compactness, roughness, hardness and oat flavour. Besides, crispiness and corn flavour were inversely proportional to the content of oat.

Ramos Diaz et al. (2013) incorporated amaranth, quinoa and kañiwa (up to 20% of solids) to corn-based extruded snacks. The authors observed that extrudates containing amaranth, quinoa and kañiwa had greater sectional expansion than the pure corn extrudates (20% amaranth >20% quinoa >20% kañiwa >100% corn).

The present study describes the impact of increasing contents of amaranth, quinoa and kañiwa on sensory and physical characteristics (stiffness, expansion, wall thickness and porosity) of corn-based extrudates. This is the first time extrudates containing amaranth, quinoa and kañiwa have been included in a comprehensive sensory study, including investigation of dynamic sensory aspects evoked by the varying grain contents. In addition, the relationship between microstructure and textural attributes was examined.

2. Material and methods

2.1. Extrudate samples

Commercial varieties of amaranth, quinoa and kañiwa were imported from South America as grains (Aduki Ltd, Finland). They were milled with a pin disc grinding device (100 UPZ-lb, Hosokawa Alpine, Augsburg, Germany) at VTT Technical Research Centre of Finland. Coarse corn flour (Polenta flour, Risenta AB, Sweden) was obtained from a local store and used as bulk ingredient. The chemical composition of the flours is shown in Table 1. The median particle sizes of amaranth, quinoa, kañiwa and corn flour were 285, 575, 240 and 747 μm, respectively.

Nine extrudate samples varying in grain type (amaranth, quinoa and kañiwa) and content of tested flours (20, 35 or 50% of solids) according to a 3 × 3 factorial design were prepared under the same extrusion conditions (Appendix A).

Extrudate samples were prepared using a twin-screw laboratory extruder (Thermo Prism PTW24 Thermo Haake, Polylab System, Germany) that consisted of seven sections with individual temperature control in six of them (each 96 mm in length); further specifications are described in Kirjoranta et al. (2012). The temperature profile was fixed at 90/95/95/100/110 °C (Sections 1–5) and 140 °C (section 6 and die). Screw speed and water content of mixture were set at 500 rpm and 14%, respectively. Salt was dissolved in distilled water and added during extrusion; the total added salt (NaCl; Meira Ltd, Helsinki, Finland) accounted for 1% of solids. Extrudate samples were freeze-dried (Heto Drywinner, Heto-Holten, Denmark) for three days prior to packaging in modified atmosphere (N_2). Extrudates were dried in order to avoid the effect of various water contents of extrudates on stiffness and sensory analyses. Freeze-drying was used in this particular study as it could prevent lipid oxidation upon drying. The by-products of lipid oxidation could have a tremendous effect on the sensory properties. The samples were stored until testing in darkness and at ambient temperature (~20 °C).

2.2. Sensory evaluation

2.2.1. Assessors

The sensory panel (n = 10, 7 females, 3 males, aged 20–30 years) was recruited from the University of Helsinki (staff and students). Training and evaluation sessions were held in English at the sensory laboratory of the Department of Food and Environmental Sciences. The study followed the approved ethical requirements of the laboratory, and an informed consent was signed by the participating panellists. Training in sensory profiling and temporal dominance of sensation (TDS) techniques lasted 12 h.

2.2.2. Sensory profiling

Training was performed to familiarize the panel with extrudates and develop a set of descriptors, references and definitions. Panellists were first introduced to various commercial extruded products in order generate a preliminary list of attributes linked to texture and taste. Reference samples (Table 2) were eventually proposed and agreed upon by the panel to define the final set of descriptors.

Each panellist evaluated all 9 samples at each of the two sensory profiling sessions. Sensory profiling was repeated once with a minimum 30-min break in between. Each sample consisted of 4 pieces (5-cm in length) that were presented in a 100-ml porcelain container, covered with plastic wrap. The order of the samples was randomized for each assessor, and samples were coded using three-digit numbers. Evaluations were conducted in individual booths at room temperature (21 °C). Panellists removed the foil and rated the intensity of the descriptors on unstructured 10-cm line scales with the anchors: “not at all” and “very”. The taste and aftertaste attributes were: overall taste, sweetness, bitterness, overall aftertaste and bitter aftertaste. The attributes for texture were: crispiness, crunchiness, hardness, hard particles and adhesiveness. Panellists were provided with water to cleanse their palates between samples. Evaluation was carried out with FIZZ Sensory Evaluation Software, Version 2.45 (Biosystemes, Courternon, France).

2.2.3. Temporal dominance sensation (TDS) test

The same panellists participated in a total of two TDS sessions. Prior to the sessions, they were presented with samples representative of the test samples. They discussed dominant perceptions during mastication and generated a final set of texture descriptors for TDS evaluation.

Table 1
Chemical composition of amaranth, quinoa, kañiwa and corn flour (Sundarrajan, 2014).

	Moisture	Content (g/100 g d.m.)		
		Protein[a]	Ash[b]	Dietary fibre[c]
Amaranth	11.3 ± 0.5	16.1 ± 1.3	2.41 ± 0.04	8.3 ± 1.9
Quinoa	11.8 ± 0.4	13.1 ± 0.4	2.2 ± 0.3	9.1 ± 2.6
Kañiwa	11.4 ± 0.4	16.7 ± 0.03	2.3 ± 0.2	16.1 ± 2.8
Corn	14.1 ± 1.0	8.2 ± 1.1	0.4 ± 0.1	5.8 ± 0.3

Measured according to:
[a] AOAC (1995).
[b] Schneider (1967), Mattila, Piironen, and Ollilainen (2001).
[c] Cho, DeVries, and Prosky (1997), Mattila et al. (2001), AOAC (2002).