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Physico-chemical properties of ready to eat, shelf-stable pasta during storage

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ABSTRACT

The changes in physico-chemical properties of RTE shelf stable pasta were studied during storage with a multianalytical and multidimensional approach (with special focus on water status) to understand the ageing process in this product.

Pasta hardness and amylopectin recrystallisation increased, macroscopic water status indicators and proton molecular translational mobility remained constant, and significant changes were measured in the proton rotational molecular mobility indicators (^{1}H FID, ^{1}H T_2) during storage.

Since the main changes observed in RTE pasta during storage were similar to those observed in other cereal-based products, it would be interesting to verify the effect of the anti-staling methods commonly used in the cereal processing industry in improving RTE pasta shelf-stability.

1. Introduction

Pasta is a very well known Italian food and its consumption is globally widespread. Pasta production has increased, globally, from 7 to 12 million tons/year in the past decade, due to the increase of pasta based dishes present in fast foods and other restaurants. The request for convenient food has pushed the pasta food industry to develop ready-to-eat, shelf-stable high quality pasta products.

For the Italian consumer "high quality pasta" is characterised by a yellow appearance (often provided by egg addition in the formulation), should leave a clear cooking water and offer "al dente" resistance to biting (Carini, Curti, Minucciani, Antoniazzi, & Vittadini, in press). The quality of ready-to-eat, shelf-stable pasta products changes during storage especially because of textural modfications. Understanding the changes that ready-to-eat, shelf-stable pasta undergoes during storage, in an attempt to clarify the fundamental causes of its textural degradation, is a very interesting challenge for a food scientist and a valuable tool to intelligently intervene on formulation and/or processing to improve the quality and shelf-stability of this product.

To the authors' best knowledge, no reports about the long term physico-chemical ageing of ready-to-eat, shelf-stable pasta are present in the scientific literature. Only one report on the physico-chemical changes occurring in shelf-stable pasta meals was recently published (Carini, Curti, Littardi, Luzzini, & Vittadini, 2013). Pasta meals were obtained by simultaneous cooking and sterilisation of pasta in the presence of tomato sauce by means of microwave heating. Pasta meals became softer during storage; water migration between pasta and sauce phases was not recorded with macroscopic water indicators (i.e. moisture content and water activity), while it was observed at a molecular level (as studied by time domain ^{1}H NMR; Carini et al., 2013). A paper reported the changes in physical (i.e. moisture content, surface colour, and texture) and microbial indicators, as well as, sensory acceptability in refrigerated lasagna meals (pasta and sauce) in an attempt to model the deteriorative reaction kinetics of the product (Olivera & Salvadori, 2012). A few other reports analysed the effect of frozen storage on quality indicators of frozen lasagna (Redmond, Gormleya, & Butlerb, 2005), frozen pasta meals (Kindt, Lercker, Mazzaracchio, & Barbiroli, 2006; Kindt, Mazzaracchio, & Barbiroli, 2008) and frozen tagliatelle (Olivera & Salvadori, 2009, 2011). Time-dependent moisture distribution in cooked pasta (lasagna shaped) has also been investigated by magnetic resonance imaging (MRI) as a function of cooking time and holding time (up to 80 min) and indicated the presence of a moisture gradient from the surface to the centre of the pasta piece immediately after cooking, that equilibrated over time (McCarthy, Gonzalez, & McCarthy, 2002). Similar MRI results were reported for spaghetti cooked and held for 15 h (Horigane et al., 2006). The changes in texture were also reported and indicated a decrease in pasta hardness (cut peak force) with water migration inside the product (Gonzalez, McCarthy, & McCarthy, 2000).

Ready-to-eat pasta is a relatively simple product, consisting mainly of gelatinised starch entrapped in a denatured and col-

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lapsed gluten network. Ready-to-eat pasta is also characterised by a relatively high moisture content (~60%) due to a large water uptake during cooking in excess water. It might be expected that the main physico-chemical modifications that affect ready-to-eat, shelf-stable pasta during storage are closely related to those involved in bread staling of cereal-based products. Multiple factors have been reported to play a role in staling including starch retrogradation (Hallberg & Chinachoti, 2002) and a change in water distribution and dynamics at macroscopic and molecular level. In particular, water molecules migrate from crumb and crust (Lin & Lineback, 1990), become partially incorporated in retrograded amylopectin crystals (Imberty & Perez, 1988), loose phase separating capability (decreased "DSC frozen water" content; Slade & Levine, 1991; Vittadini & Vodovotz, 2003), migrate between gluten and starch, (Gray & Bemiller, 2003; Slade & Levine, 1991), and reduce their molecular mobility (Hallberg & Chinachoti, 2002; Sereno, Hill, Mitchell, Scharf, & Farhat, 2007).

In an attempt to understand the ageing process in RTE shelf stable pasta, the changes in its physico-chemical properties were studied during storage with a multianalytical and multidimensional approach with a special focus on the status of water.

2. Materials and methods

2.1. Ready-to eat shelf-stable pasta

Commercial (penne shaped) dry pasta (semolina and water, residual moisture content = 12% g water/g pasta) was cooked into boiling water (pasta:water ratio 1:10) for 10 min (recommended cooking time). Pasta was drained and cooled to room temperature ("control"). About 60 g of cooked pasta were packed into multilayer (polypropylene-PP, polyethylene terephthalate-PET, polyamide-PA) pouches and subjected to sterilisation in autoclave ($F0 \geqslant 7$) to obtain precooked ready-to-eat shelf-stable pasta (RTE pasta). RTE pasta pouches were then kept at room temperature and analysed over a 63 days storage period.

2.2. Texture

RTE pasta hardness was measured using a TA.TX2 Texture Analyzer equipped with a 25 kg load cell (Stable Micro Systems, Goldalming – UK). Single pasta pieces were cut at a speed of 2 mm/s with a trigger force of 0.1 N, using a flat blade and the maximum height of the cutting peak was taken as hardness. 15 penne were cut at each storage time.

2.3. Water activity and moisture content

Water activity of RTE pasta was measured at 25 °C with an Aqualab 4TE (Decagon Devices, Inc., WA, USA).

Moisture content (MC,% g water/100 g product) of RTE pasta was determined by weight loss by drying in a forced-air oven (ISCO NSV 9035, ISCO, Milan, Italy) at 105 °C to constant weight.

At least triplicate samples of shelf-stable pasta were analysed for water activity and moisture content at each storage time.

2.4. Thermal properties

2.4.1. Frozen water content

Frozen water content was measured using a Differential Scanning Calorimeter (DSC Q100 TA Instruments, New Castle, DE, USA), calibrated with indium and mercury. 5–10 mg samples were taken and placed in stainless steel pans (Perkin Elmer, USA) that were then hermetically sealed, quench cooled to −80 °C and then heated to 130 °C at 5 °C/min. DSC thermograms were analysed using an Universal Analysis Software, Version 3.9A (TA Instruments, New Castle, DE).

"Frozen" water (at the selected experimental conditions; FW) was calculated from the endothermic peak around 0 °C (ice melting) using the following equation:

$$FW = \text{Enthalpy Ice Fusion}\left(\frac{1}{\text{latent heat ice fusion}}\right)\left(\frac{1}{MC}\right)100$$

Where FW is frozen water [%, g frozen water/g water], Enthalpy Ice Fusion [J/g product], latent heat of ice fusion is 334 J/g ice, and MC is moisture content [% g water/100 g product].

2.4.2. Amylopectin melting

The melting peak in the 50–80 °C range was assumed to correspond to the melting of recrystallised amylopectin. The enthalpy of this peak was measured (J/g) using an Universal Analysis Software (TA Instruments).

At least triplicate samples of RTE pasta were analysed for thermal properties at each storage time.

2.5. Proton Nuclear Magnetic Resonance mobility (^1H NMR)

A low resolution (20 MHz) ^{1}H NMR spectrometer (the MiniSpec, Bruker Biospin, Milano, Italy) operating at 25.0 ± 0.1 °C was used to study a wide range of proton molecular mobility by measuring the free induction decay (FID), transverse (T_2) and longitudinal (T_1) relaxation times, and proton self-diffusion coefficient (D).

About four grams of RTE pasta (10 mm high) were placed into a 10 mm NMR tube that was then sealed with Parafilm® to prevent moisture loss during the NMR experiment.

FIDs were acquired using a single 90° pulse, followed by a dwell time of 7 μs, a recycle delay of 1.2 s and a 10 ms acquisition window. ^{1}H T_2 (transverse relaxation time) was measured with a CPMG pulse sequence with a recycle delay of 1.2 s ($\geqslant 5$ ^{1}H T_1), an interpulse spacing of 0.04 ms and 4000 data points. ^{1}H T_1 (longitudinal relaxation time) was determined by the Inversion Recovery pulse sequence with an interpulse spacing ranging from 0.1 to 2500 ms, a recycle delay of 1.2 s ($\geqslant 5$ T_1) and 20 data points. ^{1}H T_2 and T_1 curves were analysed as quasi-continuous distributions of relaxation times using an UPEN software. The proton self diffusion coefficient (D) was obtained, at 25 °C, with a pulsed-field gradient spin echo (PFGSE) pulse sequence and a 40% gradient. The instrument was calibrated with acetic acid ($D = 1.08 \times 10^{-9}$ m^2/s at 25 °C).

Eight analyses on two RTE pasta samples were carried out for each NMR parameter at each storage time.

2.6. Statistical analysis

Means and standard deviations (SD) were calculated with SPSS statistical software (Version 16.0, SPSS Inc., Chicago, IL, USA). Significant differences ($p \leqslant 0.05$) among different samples were verified with by one-way-analysis of variance (ANOVA) followed by least significant difference test (LSD) at $p \leqslant 0.05$.

3. Results and discussion

Control pasta was compared to fresh RTE pasta to verify the effect of the sterilisation treatment on the moisture and textural properties of the products. Control and RTE fresh pasta were found to have comparable moisture (control 56.9 ± 0.4 g water/g sample; RTE pasta 57.1 ± 0.8% g water/g sample) and textural properties (control 10.3 ± 0.6 N; RTE pasta 10.0 ± 0.8 N) indicating that the sterilisation treatment did not significantly changes the most relevant attributes of fresh pasta.