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Influence of high-pressure processing (HPP) on physico-chemical properties of fresh cheese

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ABSTRACT

Freshly prepared rennet-coagulated soft cheese was high-pressure (HP) treated at up to 291 MPa and 29 min and using a full 2-factor central composite design of experiment, its physico-chemical properties (colour, fat, lipid oxidation, moisture and protein content, pH, and texture) were examined. HP treatment influenced significantly ($p<0.05$) the colour, fat, moisture, lipid oxidation, hardness and adhesiveness of the fresh cheese. Fat content increased apparently as moisture decreased significantly after HP treatment of above 100 MPa. Increased pressures reduced lipid oxidation but increased yellowness although the latter showed more effect over redness in the HP-treated fresh cheese. Also, increased pressures increased hardness, decreased acidity and adhesiveness in HP-treated fresh cheese although increased exposure was found to increase acidity.

Industrial relevance: High isostatic pressure for processing fresh cheese is yet to be adopted on an industrial scale. There is a need for research to provide evidence that improved properties of fresh cheese can be realized. The effects of HPP on rennet-coagulated soft Scottish cheese are investigated and the data from this study have provided points where optimized characteristic properties of HPP fresh cheese can be attained, which can serve as a lead for HPP users on fresh cheese.

1. Introduction

High-pressure pioneer Bert H. Hite first applied high-pressure processing (HPP) over a century ago and demonstrated improved milk stability, although the elementary nature of the pressure technology at that time retarded any further progress. It was about twenty years ago, however, that Japan successfully used HPP to commercially process a wide range of foods (Cheftel, 1991). Since then, HPP has been applied in various ways in the food industry. Many HPP foods are now commercially available with fruit juices and ham in Europe, guacamole in the US and a range of products in Japan including fish, surimi, rice cakes and fruit juices amongst a growing number of others (Patterson, 2005).

HPP typically involves applying pressure up to 600 MPa. Structural changes can be induced in proteins of foods at above 200 MPa. At above 500 MPa, a non-reversible effect can occur such as unfolding, aggregation and formation of gel structures. Temperature can also cause the same effects although the mechanism for this is somewhat different. The duration of the exposure to both pressure and temperature is also known to have a marked influence (Mertens & Knorr, 1992). Optimisation of pressure, temperature and time (duration of exposure to processing), are required to achieve the desired product quality. Applying the right experimental design can help to achieve the optimisation of the process. Lakshmanan, Miskin, and Piggott (2005) suggested that a partial to full factorial design can help to identify optimal processing conditions.

HPP of dairy products such as milk and cheese has been well reported. HPP of 50 to 200 MPa with longer exposures changed the proteolytic activity of cheese compared with a control, greater than cheese subjected to HPP of 200 to 400 MPa (O'Reilly, Kelly, Murphy, & Beresford, 2001). Also, texture of cheese softened under HPP (Capellas, Mor-Mur, Sendra, & Guamis, 2001). Rynne, Beresford, Guinee, Sheehan, Delahunty, and Kelly (2008) studied the effects of HPP on a 1 day old full-fat cheese and its subsequent quality and ripening, but the functional properties of fresh cheese before ripening were not described.

Cheesemakers in Scotland have had a long history of making freshly prepared soft cheeses and these cheeses are mostly produced from pasteurised cows' milk. To our knowledge, no detailed scientific study has been undertaken to evaluate the influence of high-pressure (HP) treatment on the physico-chemical properties of soft Scottish cheese. Apart from the fact that industrial scale of HPP on fresh cheese is yet to be adopted, HPP is poised to be a candidate to improve and maintain the quality of fresh cheese. HPP fresh cheese that possesses optimized characteristic qualities has not been described, and it is by this means that HPP users on fresh cheese can understand the engineering,

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scientific, technological arguments and practicalities of HP treatment. Deducing the optimal points of quality for the physico-chemical characteristics can create other avenues for further exploration of improved qualities of HPP fresh cheese (Okpala, Piggott, & Schaschke, submitted for publication). Sefa-Dedeh, Cornelius, Sakyi-Daeson and Afoakwa (2003) reported that response surface methodology (RSM) can tackle problems shaped by several variables such that optimization of responses becomes feasible. Optimum operating conditions are, thus, established such that the area occupied by the factor space corresponds to operating specifications using simple and clear models.

The aim of the present study was to evaluate a rennet-coagulated fresh Scottish cheese and examine the effects of HP treatment on its physico-chemical characteristics (colour, pH, fat, lipid oxidation, moisture, protein, and texture). A full 2-factor central composite design was used to study the physico-chemical changes at constant temperature (25 °C). Response models were generated to describe the pressure–time influence essential to establish optimum conditions to enhance the product's physico-chemical properties.

2. Materials and methods

2.1. Materials

2.1.1. Fresh rennet-coagulated cheese

One batch of freshly prepared soft cheese was obtained from a local Scottish dairy manufacturer. The milk used for the cheese preparation, which is derived from the dairy's herd of cattle, undergoes both pasteurisation (72 ± 3 °C for 30 s) as well as rennet coagulation before the soft cheese is prepared. The cheese used for the study was chosen as a representative sample of rennet-coagulated soft cheese found in Scotland. The cheese samples were packed into clean screw-capped 1.5 mL polypropylene microcentrifuge tubes (Fisher Scientific UK Ltd, Leicestershire LE11 5RG, UK) after which they were refrigerated at 4–7 °C prior to processing. Excluding the non-treated fresh cheese samples (controls), all experimental fresh cheese samples were high-pressure (HP) treated within 48 h of packaging.

2.1.2. High-pressure processing

The equipment used for high-pressure processing (HPP) was a pressure vessel constructed from 316 stainless steel with a 50 mL working capacity with maximum design operating pressure of 600 MPa (High Pressure Equipment Company, Erie, Pennsylvania 16505, USA). The chamber containing water was hydraulically pressurized to reach the required operating pressure. The operating temperature in the chamber (25 °C) was kept constant by immersion of the vessel in a constant temperature water bath (Grant Instruments [Cambridge] Ltd., Cambridgeshire SG8 6GB, UK). The temperature of the water bath was measured by an electronically-read thermocouple (RS Electronics, Michigan 48150, USA). Prior to operation, the vessel was preheated to the required temperature to effectively eliminate thermal lag time. Thereafter, cheese samples were loaded onto the pressure chamber for processing. After processing, the vessel was rapidly depressurized after which HPP cheese samples were recovered and subsequently refrigerated at 4–7 °C until required for full analysis.

2.1.3. Chemicals and reagents

Boric acid, sodium hydroxide, hydrochloric acid, sulfuric acid, 1-butanol, phosphoric acid, ammonia solution, ethanol, diethylether, petroleum ether, methyl red, potassium phosphate (buffer solution), potassium sulphate and 2-thiobarbituric acid (TBA) were obtained from Sigma-Aldrich Company Ltd. (Gillingham, Dorset SP8 4XT, UK). Kjeldahl catalyst tablets selenium (cupric selenite and cupric sulphate) were obtained from VWR International Ltd. (Lutterworth, Leicestershire LE17 4XN, UK).

2.2. Experimental design and statistical analysis

A central composite experimental design with a single centre point was used with two experimental variables of pressure and time (Table 1). Minitab 15 (Minitab Ltd., Coventry CV3 2TE, UK) was used for experimental design and data analysis. In all regression and response surface models, terms were retained only if their coefficients were significant at $p < 0.05$, and lack of fit was non-significant ($p > 0.05$). Unless otherwise stated, data were collected in triplicate and expressed as mean ± pooled standard deviation calculated across all treatments (SD).

2.3. Physico-chemical analysis

Fat, moisture, protein, pH, colour (L^*, a^* and b^* values), thiobarbituric acid-reactive substances (TBA-RS) (lipid oxidation), hardness and adhesiveness were measured on non-treated and all HP-treated fresh cheese samples. Moisture, pH and TBA-RS were also measured after 8 days of storage.

2.3.1. Moisture content

Moisture content was determined as described by Kirk and Sawyer (1991) with modifications. Approximately 1 g samples of cheese were placed in a vacuum oven (McFarlane Electrical Ltd., Tyne and Wear NE9 6HU, UK) at 105 °C overnight (18–24 h). Emerging samples were placed in a desiccator to cool to ambient temperature and moisture content determined.

2.3.2. Fat and protein

Fat content of samples of cheese was determined using the Werner–Schmid process. The protein content of all fresh cheese samples was determined using the Kjeldahl digestion process, with a Protein Factor of 6.38 (Kirk & Sawyer, 1991).

2.3.3. pH measurement

The pH of slurry prepared from approximately 1 g of cheese and 2 mL distilled water was determined using a standard pH Meter (Microprocessor pH 212 Series, HANNA Instruments™, Woonsocket, RI 02895, USA). The pH Meter was calibrated with standard buffers at pH 4.0, 7.0, and 9.0 before use.

2.3.4. Colour of cheese samples

Colour measurements were carried out immediately after high-pressurisation of fresh cheese samples using a LUCI™ 100 Colormeter Version 01-08-92 (Dr. Bruno Lange GmbH, D-14163 Berlin, Germany). Colour of cheese surfaces was described using the CIELab scale: L^*, luminance ranging from 0 (black) to 100 (white); a^* (green to red) and b^* (blue to yellow). The instrument was calibrated using a black standard tile followed by a white standard, both centrally placed over the measuring aperture. Cheese samples were carefully placed on clean microscopy slides, placed over the measuring aperture and measurements performed four times per treatment at different

Table 1
Design matrix and variable combinations in experimental samples.

Runs	Levels	
	Pressure (MPa)	Time (min)
1	150	29
2	250	5
3	50	5
4	250	25
5	50	25
6	150	1
7	291	15
8	150	15
9	9	15