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SHELF-LIFE STABILITY OF OAT GROATS PROCESSED WITH SUPERHEATED STEAM

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Abstract

Oat groat samples of approximately 13 g were processed with superheated steam (SS) at 110°C temperature, 1 m/s velocity, and two processing times – 10 and 14 min. These SS processing parameters were previously determined as the optimum parameters producing oat groats with pasting and sensory characteristics close to groats processed traditionally in a kiln. Final moisture content of SS processed groats was in the desired level between 9.0 and 9.5% wb. The SS processed groats were stored at 21°C with the objective to determine the groats shelf-life stability. The intended storage time was ~6 months, during which selected properties (pasting and sensory characteristics, colour, moisture content, free fatty acids and hexanal contents) were monitored. Oat groats processed commercially in the kiln were stored together with the SS processed groats for comparison purposes. The pasting properties and the colour of stored groats remained stable throughout the storage period. Levels of hexanal released from samples processed with SS were lower than the levels tested in samples processed in the kiln. Even after a year of storage at 21°C, the oat groats processed with SS released less hexanal than the kiln processed groats (1.4-1.7 and 6.9-7.4 ppm, respectively). The content of free fatty acids in samples processed with SS was higher than in the kiln-processed samples but remained at the same level throughout the storage. Sensory evaluation showed that all of the stored samples became blander, with the loss of toasted and oaty flavour intensities, and it was increasingly more difficult to distinguish between samples as the storage time passed.

Introduction

Oat grain (*Avena sativa* L.) is a good source of quality protein, lipids with high degree of unsaturation, minerals and vitamins, phenolic compounds as well as dietary fibre, (β-glucan), and pentosan (Drzikova et al. 2005). This exceptional combination of nutrient components is the reason of ever increasing popularity of oat products for human consumption (Cenkowski et al. 2006; Slominska et al. 2004). The main limiting factor for storage and handling of oat products is degradation of lipids via enzymatic hydrolysis followed by oxidation leading to rancidity and off-flavours development (Liukkonen et al. 1992). Prevention of the deteriorative lipid changes and rancidity development in oats is typically achieved via hydro-thermal inactivation of the lipolytic enzymes (Ganssmann and Vorwerck 1995).

Typical commercial oat processing involves steam conditioning followed by kiln drying to inactivate endogenous enzymes (Cenkowski et al. 2006; Molteberg et al. 1995). Kiln drying also develops the characteristic “oat taste”, brings about starch gelatinization to a certain degree, and helps in reduction of grain microflora (if done properly) (Bryngelsson et al. 2002; Lawrie 1999). However, the kiln drying operation is difficult to control. It is lengthy (~100 min at 88-98^{o}C) and not energy efficient. Additionally, there is a risk of grain cross-contamination with microorganisms present in the air used for cooling of the grain after kiln drying.

Recently, an alternative drying method in which superheated steam is utilized has been considered for drying of food products (Uengkimbuan et al. 2006). Superheated steam (SS) is a type of unsaturated (dry) steam generated by addition of sensible heat to saturated (wet) steam. That addition of heat increases steam temperature above the corresponding saturation (boiling point) at a given pressure. Superheated steam has the ability to transfer heat to food products to be dried and carry the evaporated moisture from the foods as long as the SS temperature is above the saturation temperature (Bórquez et al. 2008). Exposure of biological products to SS causes not only drying but also brings about other changes such as starch gelatinization, enzyme destruction, protein denaturation, colour and texture changes, and deodorization (Devahastin and Suvarnakuta 2004; Tang and Cenkowski 2000, 2001). Superheated steam drying and processing is an attractive technology offering variety of advantages over the kiln drying. These include, but are not limited to: air-free environment (providing unique opportunity for enhanced product quality), improved energy efficiency, accelerated drying rate, and reduced environmental impact when condensate is reused (Prachayawarakorn et al. 2004; Tang et al. 2005). Additionally, the alternative heat processing may modify pasting properties of oat groats which may aid in the creation of new markets for oats (Cenkowski et al. 2006).

Oatmeal or oat flakes have been staple foods in human diet for a long time and there is a continuous demand for the desired “oaty” and “toasted” flavour in these products (Bryngelsson et al. 2002). The very fact of customers being accustomed to taste and aroma of so called “traditional” (or specific) foods makes the decision of implementing new technologies into the traditional processing much more difficult (Cayot 2007). It is therefore important that oat groats processed with superheated steam meet the adequate sensory characteristics demanded by customers. The severity of SS processing used needs to be sufficient to inactivate fat-splitting enzymes and develop the characteristic flavour. Moreover, off-flavour development due to lipid breakdown when high processing temperatures are used in the absence of added moisture needs to be avoided (Cenkowski et al. 2006).

This study is a continuation of our previous work (Zmidzinska et al. 2006) aiming at optimization of SS processing parameters (steam temperature, velocity, and processing time) needed to obtain groats with unique pasting properties and acceptable sensory properties. The optimum SS processing conditions (steam temperature of 110°C, steam velocity of 1 m/s, processing time of 10 and 14 min) were used in preparation of the material to study the shelf life stability of oat groats. Oat groats processed with SS were stored together with groats that have been commercially kiln-processed at two plants within the same time period.

The objective of this study was to determine the shelf-life stability of oat groats processed with the optimum superheated steam parameters and stored at 21°C.

Materials and methods

Materials

Groat samples of different origin: (i) the SS processed groats, (ii) groats standard kilned at a commercial plant (Plant A), and (iii) groats instant kilned at a commercial plant (Plant B) were used for this study. The SS parameters used for groats processing were: 110°C steam temperature, 1 m/s steam velocity, and 10 and 14 min (referred to as SS10 and SS14, respectively).

Groat samples were stored in paper bags used in commercial oat product packaging (supplied by Can-Oat Milling Co. Portage la Prairie, MB, Canada) and stored at 21°C. Temperature and humidity in the storage chamber were monitored.

Stored samples were monitored for moisture content, pasting properties, free fatty acids content, hexanal level and groat colour. Sensory analyses of the stored samples were also performed. All of the analyses were performed on each sample at the beginning of the storage period and at arbitrary storage time intervals.

Moisture content

Moisture content (MC) of each sample was determined according to the AACC method 44-15A (AACC 2003). Groats were ground in Stein Laboratory Mill (Fred Stein Laboratories Inc., Atchison, KS, USA) to pass 0.5 mm sieve. Moisture content of resulting whole oat flour was determined in duplicate at 130°C after one hour of drying and reported as % wb (wet basis).

Pasting properties

Oat flour was obtained by grinding stored oat groats to pass 0.5 mm screen using Retsch ZM 100 Ultra Centrifugal Grinding Mill (Retsch, Haan, Germany). The flour (6 g on 14% MC wb) was slurred with 25 mL of distilled water. Viscosity of the slurry was determined with the Rapid Visco Analyser, model RVA-4 (Newport Scientific Pty, Ltd., Warriewood, Australia) according to critical pasting temperature profile. The slurry was heated from 30 to 64°C over 5 min and then held at 64°C for 15 min. Final viscosity of oat flour slurry (at the 20th minute of the test) was used for samples comparison. The critical pasting test is preferred by oat processors over the standard pasting test. The critical pasting test is performed at temperatures close to that of oat starch gelatinization which helps to reveal differences between oat samples. In standard pasting test, however, the temperature of slurry rapidly increases from 50 to 95°C, is held at 95°C and rapidly cooled back to 50°C – all within 13 min. The rapid heating and cooling regimen diminishes any differences in pasting behaviour related to starch gelatinization temperatures of different oat samples. In oat industry, the viscosity results obtained from critical pasting test done on raw groats are used to assign a particular lot of grain to a specific use or processing stream.

Hexanal and free fatty acids

The analyses of hexanal and free fatty acid (FFA) content were performed at a commercial laboratory (Medallion Laboratories division of General Mills, Minneapolis, MN, USA). Determination of free fatty acids was done according to the AOCS Ca 5a-40 official method and expressed in g/100g of fat (AOCS 1998). Hexanal determination was done with the internal procedure reported earlier by Fritsch and Gale (1977). In this method hexanal released form a sample is quantified via comparison of the gas chromatographic signal to that of an added internal standard and expressed in ppm.

Sensory evaluation

A taste panel was organized by Can-Oat Milling (Portage la Prairie) and conducted at their facility. The sensory evaluation was carried out by the panel of 6 employees of the Can-Oat Milling. All panellists, trained in the Can-Oat Milling laboratory, proved that they have the ability to taste and identify: a green (raw), overly toasted, rancid/bitter, and standard/bland oat flavours. The taste panel became familiar with the flavours in a few pre-sessions before the evaluation of stored samples began. Vocabulary of sensory attributes modified from Heinio et al. (2002) and Molteberg et al. (1996) was used. Five flavour descriptors were chosen for monitoring: oaty (normal oat flavour), raw (raw grass-hay like), toasted (Maillard reaction products), bitter (bitter taste, caffeine) and rancid (old oil). Each attribute's intensity was rated from 0 to 10 on an unstructured graphic scale (horizontal line) where left side corresponded to 0 (no intensity) and right side corresponded to 10 (highest intensity). Four samples of oat groats (5 g each) presented with 3 digit code were evaluated at each time by each panellist. Panellists were asked to smell each sample before tasting and the samples were requested to be chewed and moved around the mouth well and finally swallowed. Cleansing the palate with water between the samples was also requested. A freshly flaked quick/large flake/groat sample produced within one or two days of sensory evaluation was used as reference. Means calculated over all panellists' ratings were expressed graphically.

Colour

Minolta Chroma Meter, model CR-410 (Konica Minolta Company Ltd., Tokyo, Japan) was used for colour determination of oat groats. The instrument was calibrated with a standard yellow colour plate prior to the colour measurements. The standard three colour values (*L, a, b*) were measured for whole oat groats placed in the granular-materials attachment (CR-A50; Konica Minolta). These measurements were conducted in triplicate.

Results and discussion

Pasting properties and moisture content

The effect of storage time on final viscosity of oat flours obtained from heat processed oat groats stored at 21^{o}C is shown in Fig. 1. The pasting properties of each sample remained stable over the storage period. Groats processed commercially at Plant B were characterized by pasting viscosities lower from the three other samples. This could be contributed to the different origin of that sample.

Moisture content (MC) of groats changed during the storage at 21^{o}C and the changes are depicted in Fig. 2. Initial drop in the moisture content of samples is contributed to the equilibration process of the samples with their surroundings. The relative humidity (RH) of the surroundings was monitored but not controlled and the samples reacted to the changes in the surroundings accordingly (low RH in the winter months and lower MC of samples at that time; and higher RH during the spring and summer months expressed in higher MC of the samples).

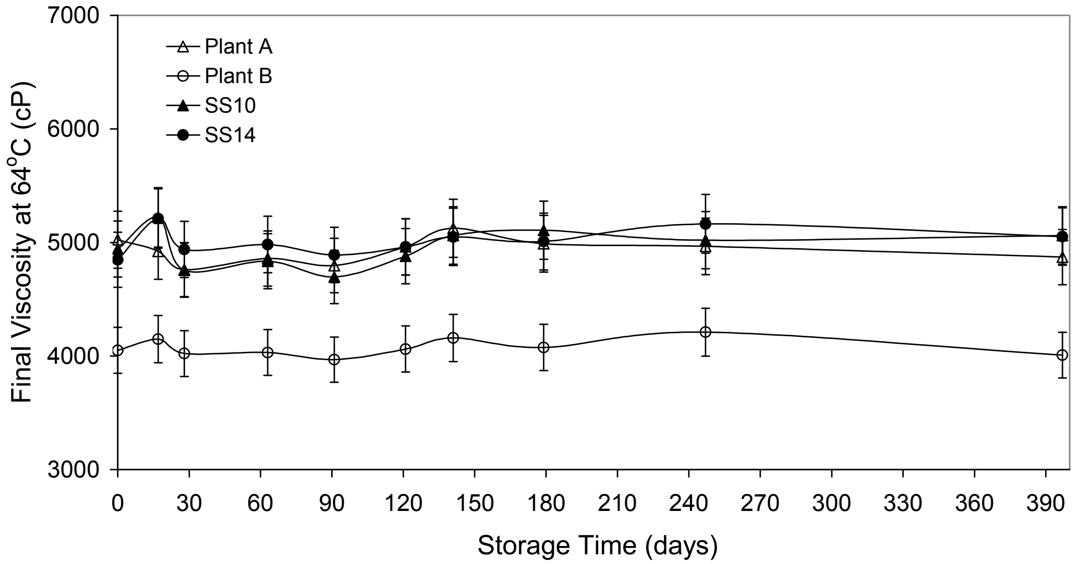

Fig. 1 The effect of storage time on the final viscosity (at 64°C) of oat flours obtained from oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110°C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21°C. Symbols represent means of two replicates and bars represent their standard deviations.

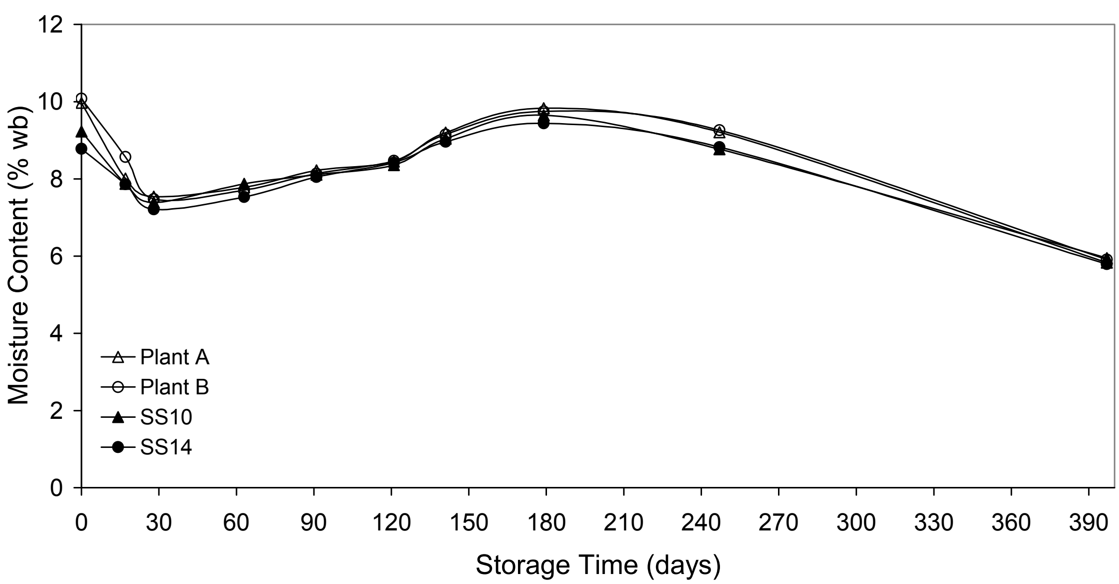

Fig. 2 Moisture content of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110°C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21°C.

Free fatty acids and hexanal contents

The initial content of free fatty acids (FFA) present in samples processed with SS was higher than in the commercial samples but remained at the same level during storage (Fig. 3). Similarly, the FFA content of commercially processed groats remained almost at the same level during the storage.

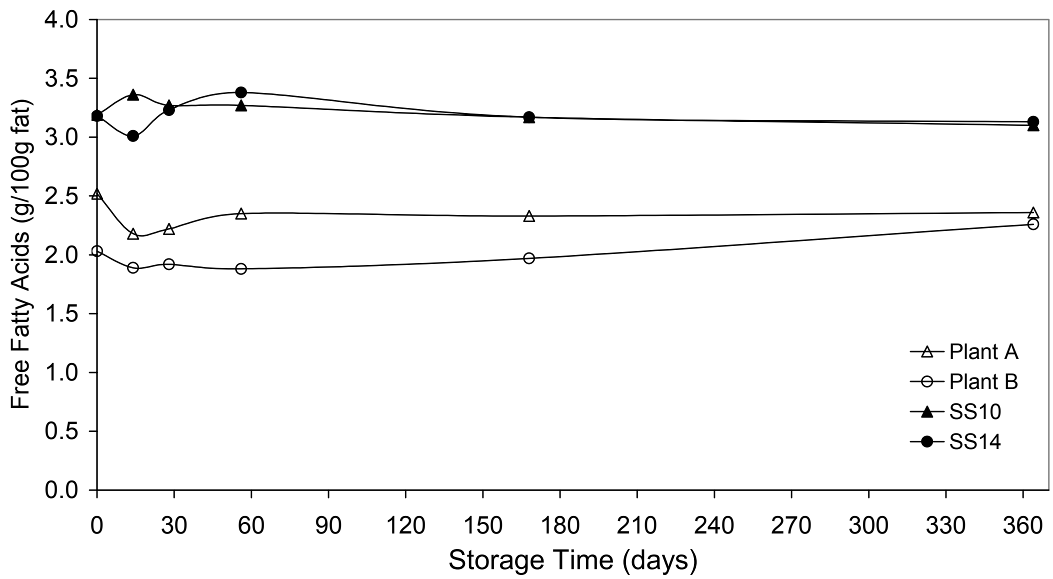

Fig. 3 The effect of storage time on free fatty acids content of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110°C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21°C.

Generally, levels of hexanal released from the samples processed with SS were lower than the levels tested on samples processed at two commercial plants (Fig. 4). That can indicate that the process in which kiln drying is involved causes "over-processing" of groats and their stability is jeopardized. A large increase in the amount of hexanal released from commercially processed groats after 164 days of storage can be attributed to the onset of oxidative rancidity.

The examination of rancidity development in breakfast cereals was carried out by Fritsch and Gale (1977) where the simultaneous hexanal determination by the gas chromatography method and the sensory evaluations were performed on stored samples. The increase in hexanal peak was noted prior to the onset of rancid odours. That suggested that hexanal method can be used as a measure of deterioration before the onset of rancid odours detectable by humans. Also, whenever rancid odours were first noted by the panellists, the hexanal concentration in samples was between 5 and 10 ppm.

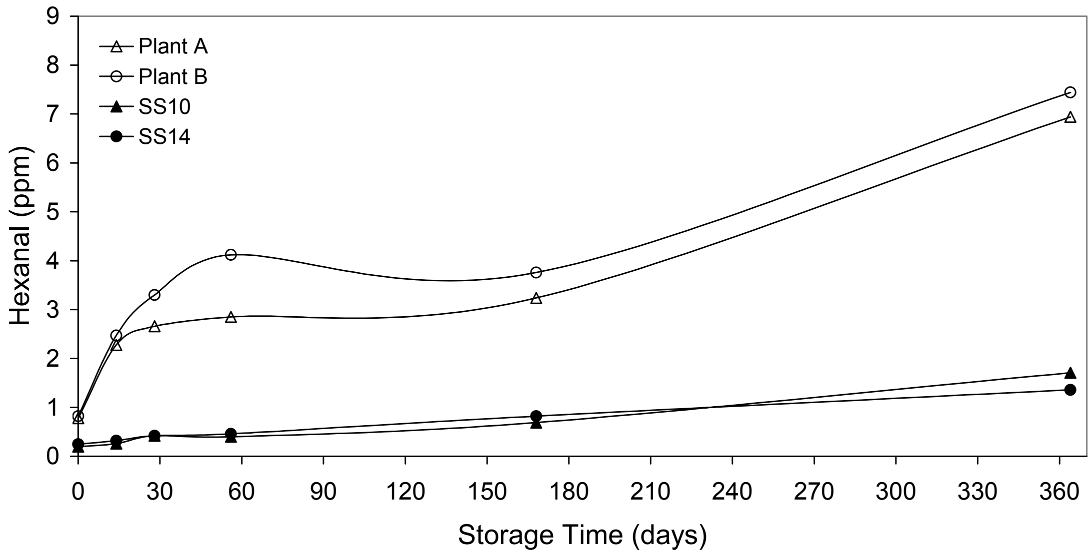

Fig. 4 The effect of storage time on level of hexanal released from oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110^{o}C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21^{o}C.

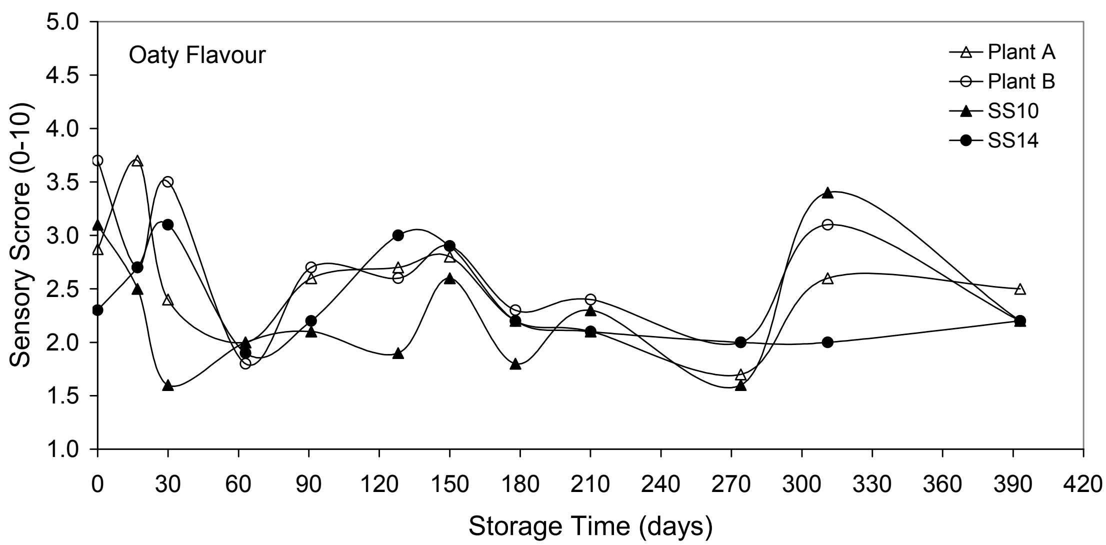

Fig. 5 The effect of storage time on intensity of oaty flavour of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110^{o}C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21^{o}C.

Sensory analysis

The effects of storage time on the intensity of oaty, toasted, raw, bitter, and rancid flavours of oat groats are shown in Figs. 5-9, respectively. At the beginning of storage period the flavour of the

SS processed groats was unique (lower toasted and higher raw flavour intensities) from the two commercially processed groats. However, this flavour difference between the groats became less noticeable as the storage time passed. Slight bitterness of the samples processed with SS, especially the ones processed for 10 min, was noted only at the beginning of the storage study.

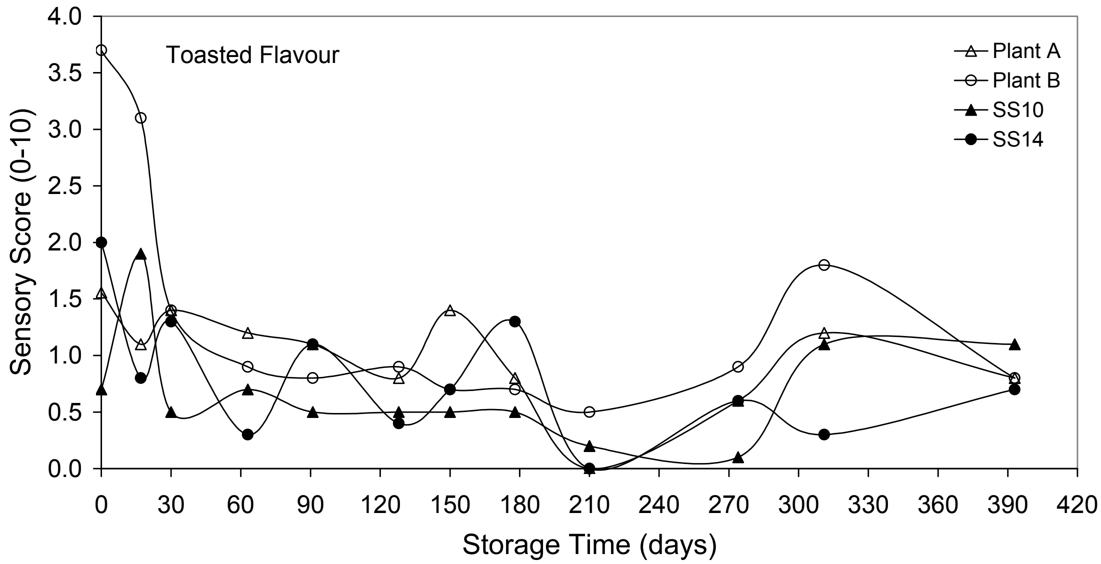

Fig. 6 The effect of storage time on intensity of toasted flavour of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110^{o}C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21^{o}C.

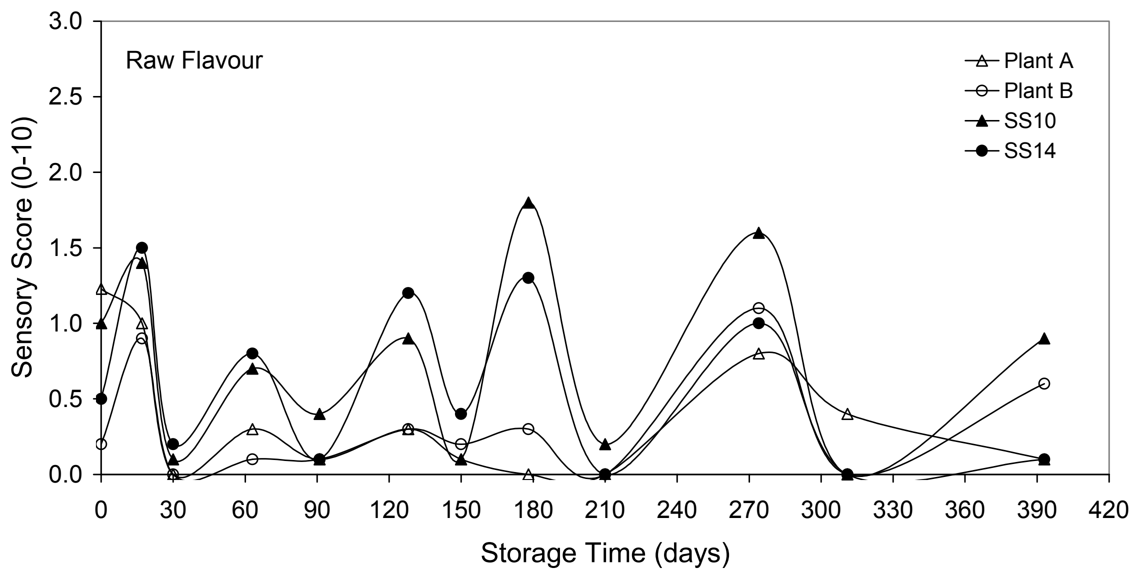

Fig. 7 The effect of storage time on intensity of raw flavour of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110^{o}C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21^{o}C.

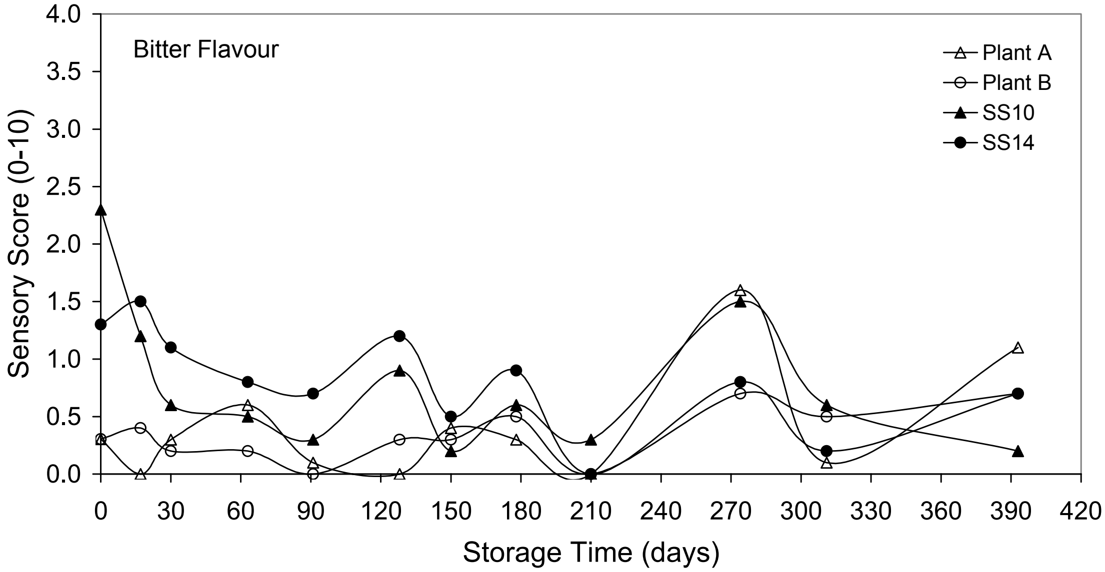

Fig. 8 The effect of storage time on intensity of bitter flavour of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110°C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21°C.

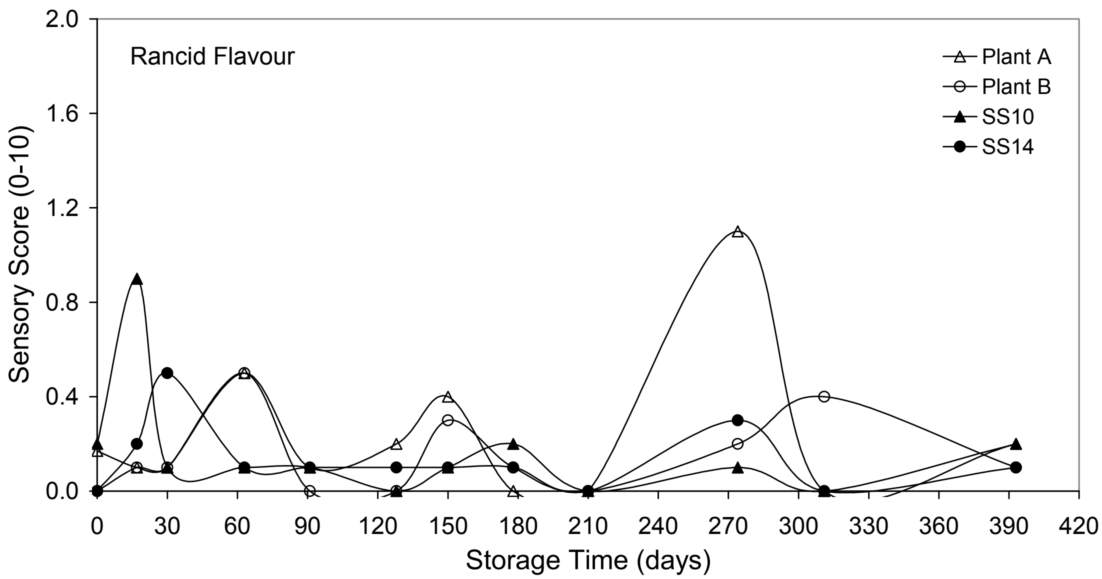

Fig. 9 The effect of storage time on intensity of rancid flavour of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110°C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21°C.

Colour

Colour of oat groats remained stable throughout the storage period. Some fluctuations in the colour values were observed during storage and were attributed mostly to the heterogeneous nature of the material (some broken kernels mixed with sound kernels). As it is shown in Fig. 10, the *L* values of groats stored at 21°C were not greatly affected by the storage time. The *a* and *b* values followed the same trend.

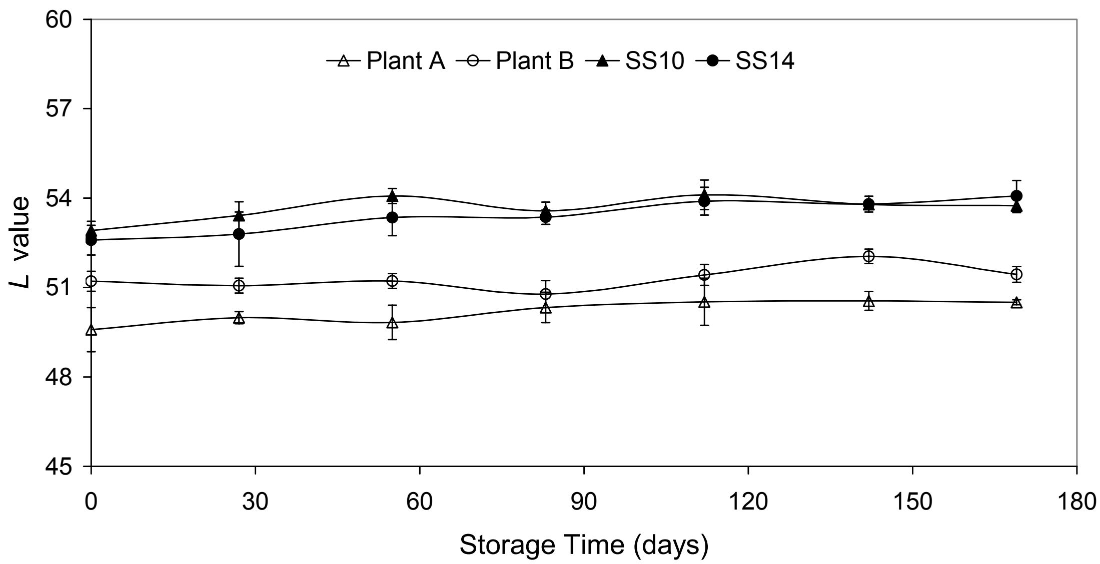

Fig.10 The effect of storage time on *L* value (lightness) of oat groats processed commercially (Plant A and B) or processed with superheated steam (SS) at 110°C and 1 m/s for 10 and 14 min (SS10 and SS14, respectively), and stored at 21°C. Symbols represent means of three replicates and bars represent their standard deviations.

Summary and Conclusions

The shelf-life stability of oat groats processed with superheated steam and stored at 21°C was acceptable and exceeded the intended storage time period of ~6 months.

The pasting properties and the colour of stored groats remained stable throughout the storage period. The content of FFA in samples processed with SS was higher than in the kilned samples (3.0-3.2 and 1.9-2.4 g/100g fat, respectively) but remained stable during storage. Similarly, FFA content of the kilned samples remained almost at the same level during the storage. Compared to SS processing, the kiln processing caused increased levels of hexanal released from these oat groats during storage (up to 6.9-7.4 and 1.4-1.7 ppm after a year of storage for kiln and SS processed groats, respectively). That can mean that the traditionally processed samples are “over-processed” and their shelf stability is jeopardized. Sensory evaluation indicated that all of the stored groats became blander (loss of toasted and oaty flavour intensities) and it was increasingly more difficult to distinguish between the samples as the storage time progressed. Moisture content of stored groats reflected the changes occurring in the surroundings which were related to seasonal changes in the humidity of the air.

Processing of oat groats with SS provides a shelf-stable product of unique pasting properties, flavour and brighter appearance from kiln processed groats. Because SS processing is several times shorter than kiln processing (10-14 min at 110°C and up to 100 min at 88-98°C, respectively) it allows for substantial savings of production time and costs and offers an alternative method of heat treatment for oat groats.

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