Processing of Frozen Parboiled Rice Product

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ABSTRACT

Laboratory parboiled rice was frozen using two different freezing processes. One process was immersing the sample in liquid nitrogen (N-freezing process), then keeping it at -20°C, and the other process was direct freezing in the freezer at -20°C (F-freezing process) and keeping it there. Samples were then stored for 7 days. Comparison of various properties of cooked frozen rice samples from the two different freezing processes were done using Differential Scanning Calorimetry (DSC) to determine the thermal requirements for starch retrogradation. Hardness value of both methods increased from fresh cooked parboiled rice until day 3 after which the hardness value decreased and showed non significant difference for the freeze-thaw samples at day 7. Starch retrogradation by DSC of N-freezing process caused less enthalpy to melt the starch crystalline material than F-freezing process, especially when the time of storage and the freeze-thaw cycles of rice samples increased, but the difference was non significant for sensory evaluations.

Frozen parboiled spicy rice products were processed for comparison by contact plate freezer (C-freezing process) and cryogenic freezer using liquid nitrogen as batch system (N-freezing process) before keeping in a freezer at -20°C for 5 days, and then freeze-thawed everyday. Hardness value of both frozen parboiled spicy rice processes increased from fresh cooked rice until day 3, after which the hardness values decreased and showed non significant difference for the freeze-thaw samples at day 5. There were no significant differences in sensory evaluations.

Key words: parboiled cooked rice, freezing, retrogradation

INTRODUCTION

In the world market, Thailand exports rice about 1/6 of its total amount as parboiled milled rice which passes through a parboiling process before milling. Hardening of the grain due to gelatinization of starch during parboiling results in reduced breakage property of the grain and therefore increases head rice yield during milling. It contains vitamins and minerals more than the white milled rice of the same variety (Luh, 1991).

Frozen foods retain nutrients and freshness more than canning or drying foods, so the frozen cooked parboiled rice is a nutritious food product. Texture is a highly important quality of cooked rice products but the freezing process causes severe damage to cell membrane and starch gel network structure of cooked rice and may cause excessive softening. Slow freezing results in formation of large ice crystals and irreversible damage to cell structure and texture as critical for favorable characteristics of rice.

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Perdon *et al*. (1999) investigated the texture and degree of starch retrogradation of cooked rice samples of Bengal (16%, medium amylose content) and Cypress (25%, high amylose content) that were kept at -13, 3, 20 and 36°C for 4 days. Firmness of rice samples which kept at -13°C increased while the samples kept at 3°C decreased. At 20°C, retrogradation occurred, especially in Cypress.

The stability of starch gel during freeze-thaw cycling enhances its potential use in food products. This stability has been measured by using Differential Scanning Calorimetry (DSC) (White *et al*., 1989).

The objectives of this research were to compare the effects of different freezing processes on the texture and starch retrogradation of frozen cooked parboiled rice and frozen cooked parboiled spicy rice.

MATERIALS AND METHODS

Materials

Laboratory parboiled rice (Sitachitta and Naivikul, 2003), Chai Nat 1 rice variety (27% amylose content) from Supanburi, Thailand, was kept at -5°C before cooking having the optimum rice and water ratio at 1: 2.3 for frozen cooked parboiled rice (frozen rice) and 1: 2.5 for frozen cooked parboiled spicy rice (frozen spicy rice).

Part I : Frozen cooked parboiled rice (frozen rice)
Freezing process

The cooked parboiled rice was frozen by using two different freezing processes. One was ultra rapid freezing by immersing the sample in liquid nitrogen (N-freezing process) for 15 seconds, then keeping it at -20°C in the freezer, and the other was directly freezing it in the freezer at -20°C (F-freezing process) and then keeping it in the same freezer. All frozen rice samples were stored for 7 days. During storage, both frozen rice samples were divided into two groups, either freeze-thawed everyday (T-frozen rice) for 7 days or kept without thawing (W-frozen rice) for 7 days.

Freeze-thawing stability

The thawing condition was at 30°C in a water bath for 1 hour. The remaining samples were kept in the freezer at -20°C for further freeze-thaw cycles. Seven cycles of freeze-thaw for the frozen rice were done before analysing freeze-thaw stability by measuring the hardness and retrogradation.

Texture measurement

The Ottawa cell of Texture Analyser (TA-XT2) was used to measure the hardness of frozen rice that was reheated by microwave at highest level for 4 minutes on the analysed day. Thirty grams of each sample were placed into the Ottawa cell. This cell consisted of a 3 mm diameter extrusion plate and square sharp plunger that traveled through the cell while extruding the rice sample. The plunger speed was 0.5 mm/sec until reaching 70% of sample height. The maximum force was measured that refered to hardness of parboiled rice grain and the values related with the retrogradation of starchy in parboiled rice grain increasing when the time storage increased. (Stable Micro System, 1995).

Starch retrogardation measurement

All samples were dehydrated by mixing with 95% ethanol (1:4 w/w) for 15 minutes and then dried at 35°C. The dried samples were ground and passed through a 100 mesh sieve.

The starch retrogardation was analysed by using a Differential Scanning Calorimeter (DSC) (Perkin Elmer Pyris 1). Samples of 12-13 mg (30:70 w/w of flour : deionized water) were prepared in an aluminum pan and the empty pan was used for reference. Scanning temperature was from 30° to 95°C at speed of 10°C/min. The thermogram of retrograded starch enthalpy (ΔH,

J/g) required to melt the crystalline material in each sample was produced (modified method from Kim *et al*., 1997).

Sensory evaluation

Ten trained panelists used a linear scale (15 cm ; 1 was minimum and 15 was maximum intensity for each characteristic) to evaluate attributes, such as complete grain, cohesiveness and overall acceptability of the frozen rice.

Part II : Frozen cooked parboiled spicy rice (frozen spicy rice)
Freezing process

The cooked parboiled spicy rice products were frozen by two different processes, namely contact plate freezer (C-freezing process) and cryogenic freezer using liquid nitrogen as batch system (N) process, before keeping in the freezer at -20°C for 5 days and then freeze-thawing everyday.

Freeze-thawing stability

Frozen spicy rice had five freeze-thaw cycles with the same conditions as frozen rice before analysing freeze-thaw stability by measuring the hardness**.**

Texture measurement

Frozen spicy rice reheated by microwave at the highest level for 4 minutes on the day of analysis had their hardness measured with the same conditions as frozen rice**.**

Sensory evaluation

Ten trained panelists used a linear scale (15 cm ; 1 was minimum and 15 was maximum intensity for each characteristic) to evaluate attributes, such as spicy flavor, complete grain, cohesiveness and overall acceptability of the frozen spicy rice.

RESULTS AND DISCUSSION

Part I: Frozen rice
Texture properties of frozen rice

The hardness value of the seventh day samples, freeze-thaw and without freeze-thaw rice sample with different freezing methods; freezer (F-process) and immersing in liquid nitrogen (N-Process), showed significant differences (P<0.05) from fresh cooked rice that had less hardness values than both freezing processes of frozen rice especially without freeze-thawing during 7 days storage. The hardness of freeze-thaw 7 cycles of both freezing processes increased from fresh cooked rice but lower than without freeze-thawing. The trend for 3-4 cycles of both freezing methods showed the highest value but the value at 5-7 cycles decreased so that the total (7 cycles) showed as non significance.

While Lee *et al*. (1996) measured the textural properties of cooked parboiled rice (long and short grain rice varieties) under various freezing conditions and found that the hardness of cooked parboiled rice increased upon freezing.

Oh (1998) determined the effects of various thawing methods (pressure cooking, conventional cooking, microwave heating and thawing) and storage periods (10, 30 and 90 days) on the quality of frozen cooked rice, the results showed no significant decrease in quality characteristics of freeze-thaw cooked rice during 90 days storage period, however thawing at room temperature caused a significant decrease in quality characteristics.

Comparing the hardness values of rice with different freezing methods, the results showed that frozen rice by the N-process without freeze-thawing (LNW7) had more hardness than frozen rice by F-process (LFW7). In the F-process, the rice sample had more firmness than the N-process, because the N-process had a more rapid freezing rate, especially with freeze-thawing such as LNT7 which had less hardness than LFT7. Also the size

of ice crystals in the frozen rice grain was smaller so these caused less damage to the network structure of starch in the rice grain than with the F-process when freeze-thawing occurred. The rice samples from N-process showed more uniform, unbroken grains than the F-process during storage. The rice grains from the F-process were broken so the results from the Texture Analyser showed less hardness value (Figure 1).

Choi and Rhee (1995) studied the effects of freezing rate (3, 5, 7 or 12 h) and storage temperature (-20 and -70°C for up to 90 days) on the degree of retrogradation, hardness, adhesiveness and microstructure of cooked rice samples. The results showed that cooked rice stored at -20°C retrograded faster and hardness value higher than that stored at -70°C. Adhesiveness values of the thawed, cooked rice decreased during freezing and more rapidly at the higher freezing rate. During the frozen storage period, the sizes of ice crystals in the cooked rice samples increased due to recrystallization taking place and the ice crystal formation and growth damaged the microstructure of the cooked samples.

Retrogradation properties of frozen rice

Comparison of the retrogradation
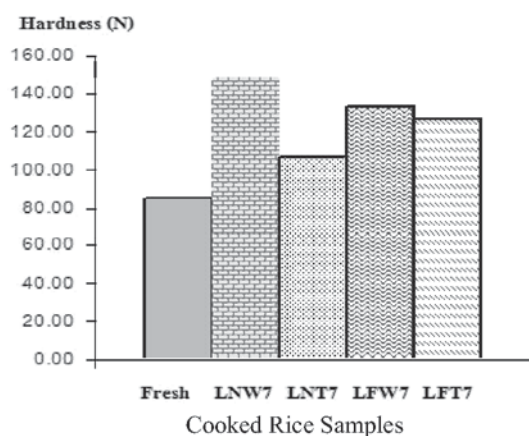
Figure 1 Hardness value of cooked frozen rice samples from N-process and F-process at days 7 of freeze-thaw cycle.

enthalpy using the DSC of both types of frozen rice showed that the N-process caused less enthalpy to melt the starch crystalline structure than the F-process and retrogradation enthalpy increased as the time of storage samples increased, especially for the freeze-thawed rice samples. The starch retrogradation enthalpy of the seventh days showed significant ($P<0.05$) differences among fresh cook (Lcook, 0 J/g), LFW7 (0.13 J/g), LFT7 (0.47 J/g), LNW7 (0.09 J/g) and LNT7 (0.53 J/g) (Figure 2).

Sensory evaluation of frozen rice

Test panelist's line scores of the two freezing methods were nosignificantly different at day 7 for the completed grain, cohesiveness and the acceptance characteristics (Table 1 and Figure 3). The rice samples from N-process showed more uniform, unbroken grains than those of the F-process during storage (Figure 4).

Part II: Frozen spicy rice
Texture properties of frozen spicy rice

The hardness value from 0-5 cycles of freeze-thaw rice samples for both freezing methods; the contact plate freezer (C-process) and the cryogenic freezer using liquid nitrogen as batch system (N-Process), showed non significantce ($P<0.05$). The trend of hardness increased from 0 cycles until 3 cycles of both freezing methods after that the hardness of all rice samples decreased at
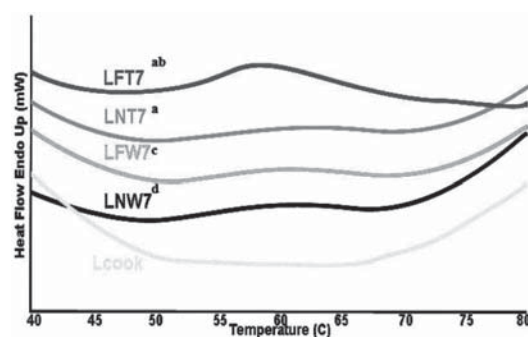
Figure 2 The retrogradation enthalpy of cooked frozen rice samples from N-process and F-process at day 7 of freeze-thaw cycle.

4-5 cycles (Figure 3) and it was founded that the amount of rice grain increased cracking at the final (cycle 5) rather than the first cycle so that the highest value showed non significant difference.
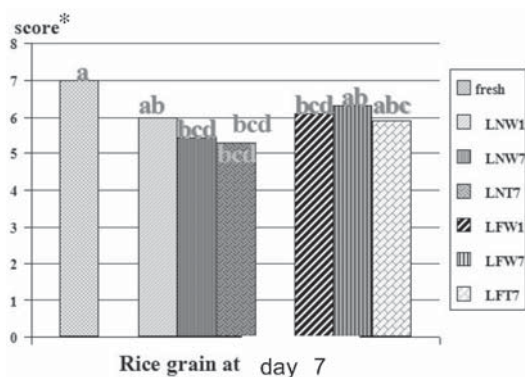
(Figure 5).

Comparing the freezing process, the hardness value of the N-process and the C-process were not significantly different at 5 cycles.
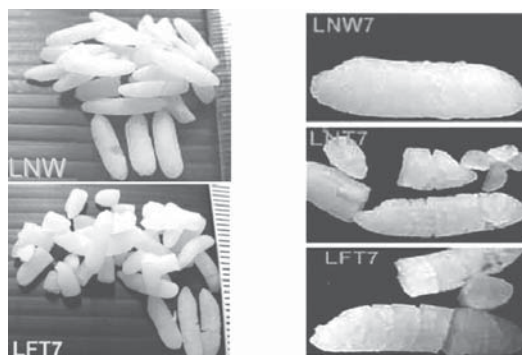
Table 1 Sensory e valuation of frozen parboiled rice over seven days freeze-thaw cycle.

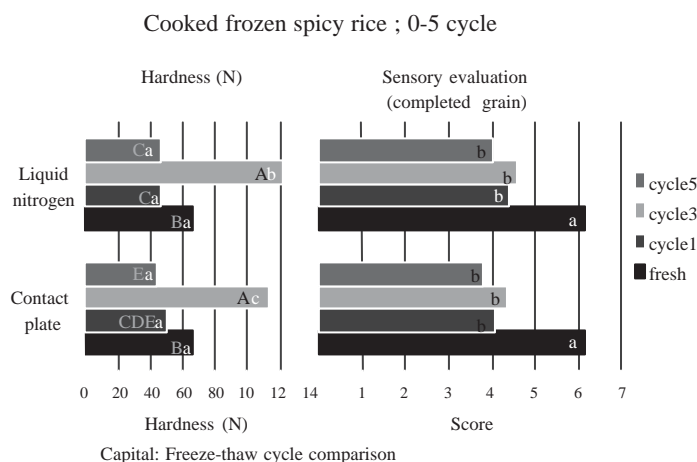| Sample	Completed grain	Cohesiveness	Acceptance
LNW1	6.00 ab	6.30 a	4.80 ns
LNW7	5.40 bcd	6.00 ab	5.80 ns
LNT7	5.30 bcd	5.40 ab	4.80 ns
LFW1	6.10 bcd	5.40 ab	5.80 ns
LFW1	6.30 ab	5.90 ab	5.00 ns
LFT7	5.90 abc	6.10 a	6.10 ns

*   High score means more complete grain

Figure 3 Complete grain characteristics of N-process and F-process at day 7 of freeze-thaw cycle.

Figure 4 The N-process and F-process of frozen parboiled rice at day 7 of freeze-thaw cycle.

Cooked frozen spicy rice ; 0-5 cycle

Capital: Freeze-thaw cycle comparison

Figure 5 Hardness value and completed grain characteristics of N-process and C-process at day 5 of freeze-thaw cycle.

Table 2 Sensory evaluation of frozen rice at   day 5 freeze-thaw cycle.

Process	Spicy flavor	Completed grain	Cohesiveness	Acceptance
N	5.08 ab	3.99 b	5.68 a	3.55 c
C	5.06 a	3.77 b	5.19 a	3.82 c

Sensory evaluation of frozen spicy rice

Test panelist's line scores of both freezing methods at the final cycle (day 5) were not significantly different of the spicy flavor, the complete grain, the cohesiveness and the acceptance (Table 2) .

Freeze-thaw cycle from 0-5 cycles had an effect on the quality of all samples and the scores of 0-3 cycles were more than those of 4-5 cycles.

CONCLUSION

Comparing the freezing processes, the N-process (immersing in liquid nitrogen and freezing by cryogenic freezer using liquid nitrogen as batch system) caused the sizes of ice crystals in the frozen grain to be smaller and damaged the network structure of starch in grains less than those of the F-process for the cooked parboiled rice. So the rice samples from N-process showed more uniform, unbroken grains than from F-process. The N-process caused less enthalpy to melt the starch crystalline material than the F-process. The retrogradation enthalpy of both methods increased when the storage time increased, especially for the freeze-thaw rice samples but were not significant in the result of sensory evaluation as same as the result of sensory evaluation of the parboiled spicy rice for the C-process and the N-process at 5 freeze-thaw cycles.

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