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Effect of controlled atmosphere with nitrogen (N_2-CA) on fatty acid value of paddy under different temperature conditions

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ABSTRACT

The experiment was carried to study the effect of controlled atmosphere with nitrogen (N_2-CA) at three nitrogen concentrations (90, 95 and 98%) on the fatty acid value of paddy (*Oryza sativa* L.) with two m.c. (13.6% and 15.1%) stored at three temperatures (20, 25 and 30ºC) and by continuous N_2-CA, alternate N_2-CA and conventional methods for 18 months. The results revealed that both continuous and alternate N_2-CA storages could delay the increase in fatty acid value of paddy, and the effect of former treatment was significantly higher than that of the latter; alternate N_2-CA storage at 20°C and with 90% nitrogen concentration showed nearly no delaying effect; and the fatty acid value of paddy of N_2-CA storage nitrogen remained at the same level after being unsealed. These results obtained provide granaries with basic data to select appropriate storage methods (temperature control, way of filling nitrogen and so on) depending on the control target of fatty acid value as well as the moisture content of paddy.

Key words: Alternating purging nitrogen storage, Fatty acid value, Nitrogen storage, Paddy

Grain storage of controlled atmosphere with nitrogen (N_2-CA) is a manual control method of oxygen reduction (such as nitrogen generator or deoxidizer) to prevent and treat insect pests in stored grain, inhibit mould reproduction, control grain respiration and finally maintain grain quality.

Application of N_2-CA grain storage has been expanding in China; therefore, to deeply understand the effect of N_2-CA on the fatty acid value of paddy, a series of simulation experiments have been carried out in actual warehouses to analyze the effect of different N_2-CA patterns on the fatty acid values of paddies with different moisture contents at different temperatures and provide data support for the application of N_2-CA grain storage.

MATERIALS AND METHODS

Simulation labs

Three labs at different temperatures (20±0.2ºC, 25±0.2ºC and 30±0.2ºC) were prepared according to the experimental conditions listed on Table 1.

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Experimental grain

Paddy of the same breed growing at the same condition produced by Shuzhouxiang Rice Production Base, Chongzhou Agricultural Industry Demonstration Park, Sichuan, was selected. After a natural drying processing, two kinds of paddy with different m.c. (13.6 and 15.1%) were obtained and then stirred to mix well. Every experimental bottle (50 L) was filled with 20 kg of each kind of paddy.

Experimental method

Experimental bottles in each temperature control lab were connected, shown as Fig. 1. Air tightness of each experimental bottle and each group of experimental bottles was checked to guarantee the airtightness of whole experimental equipment.

Nitrogen filling experiment

The experimental nitrogen concentrations respectively were 98%, 95% and 90%. First, 99.9% nitrogen was filled till the nitrogen concentration reached the target, and then 98%, 95% and 90% standard mix gas (composed of nitrogen N_2 and oxygen O_2) were filled, respectively, through micro- air flow

Table 1 Experimental conditions for the research on the effect of N_2-CA on paddy fatty acid value

Grain	Moisture	Temperature	Nitrogen concentration	Filling pattern	Inspection frequency
Paddy	13.6% 15.1%	20ºC 25ºC 30ºC	98% 95% 90%	Continuous N_2-CA Alternate N_2^1-CA	Sample every three month and inspect fatty acid value

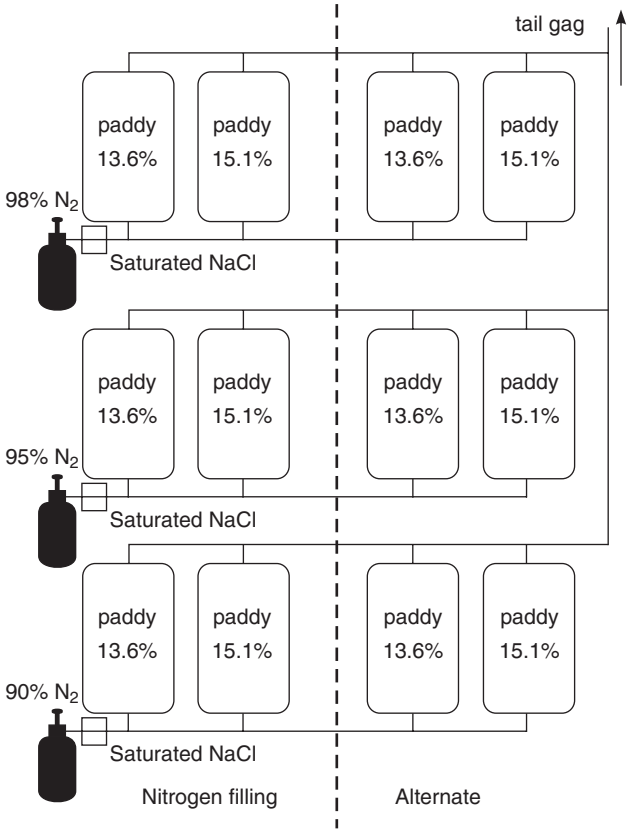

Fig. 1. Presentation of nitrogen filling experiment

to maintain the target nitrogen concentration with the allowable error range of ± 0.2%. The concentration of nitrogen was calculated by deducting the oxygen concentration from 100%. The nitrogen monitor equipment was: P860 made by Chengdu Chang-ai Electric Technology Co., Ltd.

Nitrogen filling patterns

'Continuously controlled atmosphere with nitrogen' (continuous N_2-CA) refers to maintaining a target nitrogen concentration for 18 months; 'alternately controlled atmosphere with nitrogen' (alternate N_2-CA) means firstly maintaining a target nitrogen concentration for 6 months, emitting and conventionally storing for 6 months (at the same temperature) and then maintaining the target nitrogen concentration for another 6 months; and the contrast experiment is a conventional storage at the same temperature for 18 months.

Sampling and inspection

Sample every three months and inspect the fatty acid value of paddy in accordance with the *General Rules of Inspecting Grain, Oilseeds and Vegetable Oils* (GB/T 5490-2010).

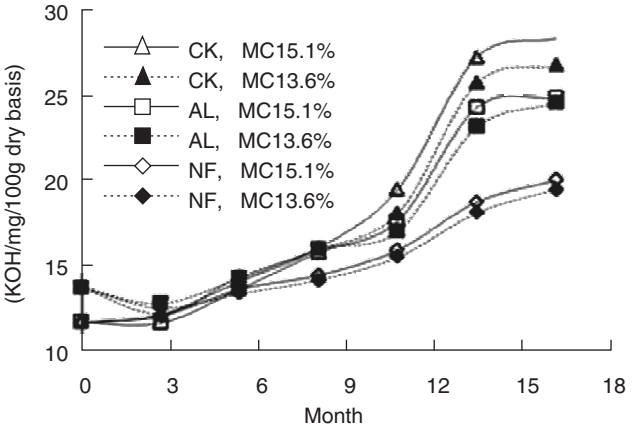

Fig. 2. Effect of filling patterns of 98% nitrogen on the fatty acid value of paddy at 30ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

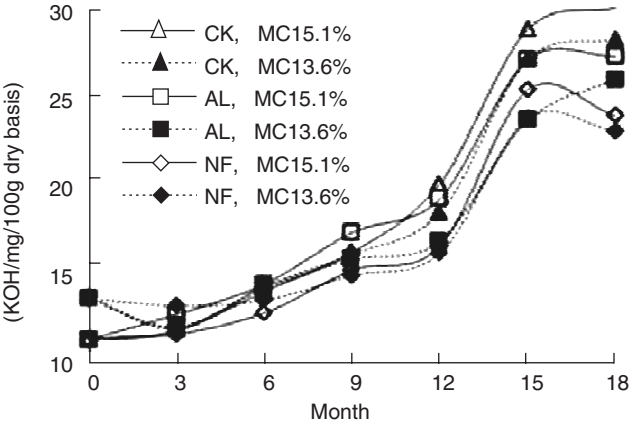

Fig. 3. Effect of filling patterns of 95% nitrogen on the fatty acid value of paddy at 30ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

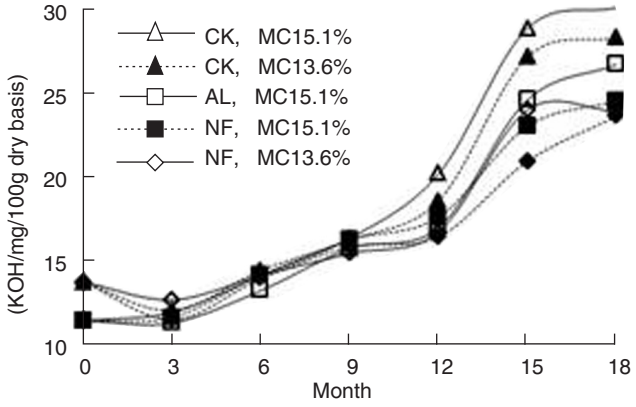

Fig. 4. Effect of filling patterns of 90% nitrogen on the fatty acid value of paddy at 30ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

RESULTS AND ANALYSIS

Effect of nitrogen filling patterns on fatty acid value of paddy at 30ºC

Figs 2–4 showed that at 30ºC:

1. CA storage with 98, 95 and 90% nitrogen could effectively delay the increase in fatty acid value of paddy, and higher nitrogen concentration performed better. For instance: (i) compared with the conventional storage, the reductions in fatty acid value of paddy with 13.6% moisture, respectively, stored in 98, 95 and 90% nitrogen with continuously filling pattern for 18 months were 8.1, 5.1 and 4.3; and likewise; and (ii) the reductions in fatty acid value of paddy with 15.1% moisture, respectively, stored in 98, 95 and 90% nitrogen with continuously filling pattern for 18 months were 9.3, 6.1 and 3.4.
2. Continuous N_2-CA storage performed better than alternate N_2-CA storage in delaying the increase in fatty acid value, and higher nitrogen concentration performed better. For instance: (i) compared with the conventional storage, the reductions in fatty acid value of paddy with 13.6% moisture respectively stored in 98%, 95% and 90% nitrogen with continuous filling pattern for 18 months were 8.1, 8.1 and 4.3, and likewise, the reductions in fatty acid value of paddy with 13.6% moisture, respectively, stored in 98%, 95% and 90% nitrogen with alternate filling pattern for 18 months were 2.4, 2.4 and 2.4; and likewise; and (ii) compared with the conventional storage, the reductions in fatty acid value of paddy with 15.1% moisture, respectively, stored in 98%, 95% and 90% nitrogen with continuous filling pattern for 18 months were 9.3, 6.1 and 3.4, and likewise, the reduction in fatty acid value of paddy with 15.1% moisture, respectively, stored in 98, 95 and 90% nitrogen with alternate filling pattern for 18 months were 3.9, 2.7 and 3.9 respectively.
3. After six months of CA storage with 98, 95 and 90% nitrogen, the paddies were unsealed for alternate N_2-CA storage, and the increases in fatty acid value of paddy were less than that of the contrast sample, which meant unsealing after N_2-CA storage at 30ºC had no influence on fatty acid value of paddy.

Effect of nitrogen filling patterns on the fatty acid value of paddy at 25ºC

The Figs 5-7 showed that at 25ºC:

1. CA storage with 98, 95 and 90% nitrogen could effectively delay the increase in fatty acid value of paddy, and higher nitrogen concentration performed better. For instance: (i) compared with the conventional storage, the reductions in fatty acid value of paddy with 13.6% moisture stored in 98, 95 and 90% nitrogen with continuous filling pattern for 18 months were 6.1, 5.3 and 3.9 respectively; and likewise; and (ii) the reductions in fatty acid value of paddy with 15.1% moisture stored in 98, 95 and 90% nitrogen with continuous filling pattern for 18 months were 8.0, 6.6 and 5.7 respectively.
2. Continuous N_2-CA storage performed better than alternate N_2-CA storage in delaying the increase in fatty acid value, and higher nitrogen concentra-

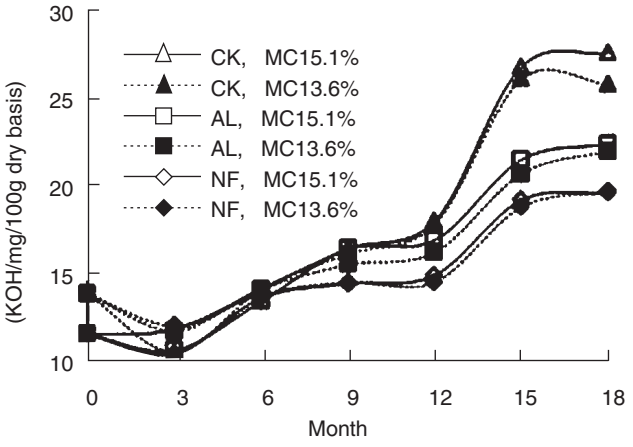

Fig. 5. Effect of filling patterns of 98% nitrogen on the fatty acid value of paddy at 25ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

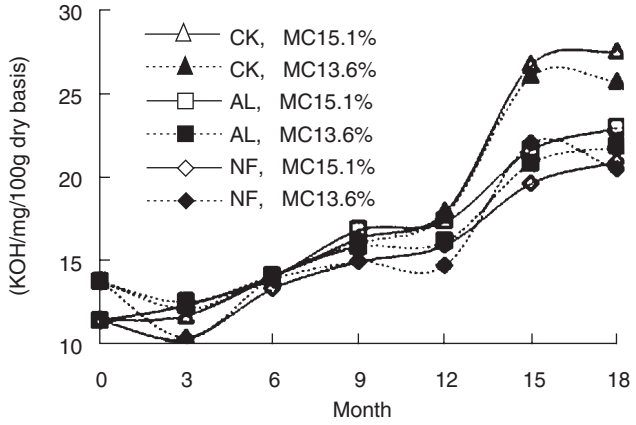

Fig. 6. Effect of filling patterns of 95% nitrogen on the fatty acid value of paddy at 25ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

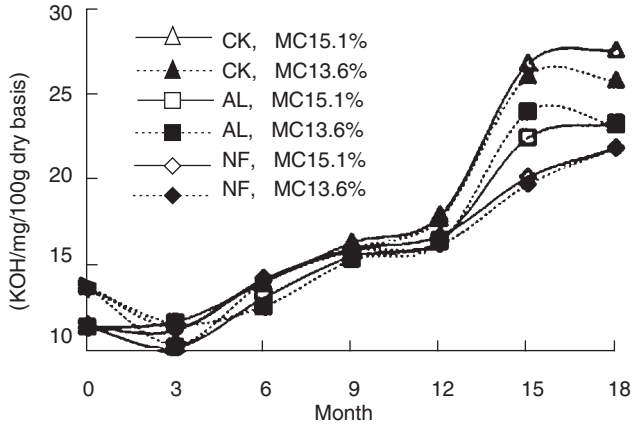

Fig. 7. Effect of filling patterns of 90% nitrogen on the fatty acid value of paddy at 25ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

tion performed better. For instance: (i) compared with the conventional storage, the reductions in fatty acid value of paddy with 13.6% moisture, respectively, stored in 98, 95 and 90% nitrogen with continuous filling pattern for 18 months were 6.1, 5.3 and 3.9 and likewise, the reductions in fatty acid value of paddy with 13.6% moisture, respectively, stored in 98, 95 and 90% nitrogen with alternate filling pattern for 18 months were 3.8, 3.8 and 2.6; (ii) compared with the conventional storage, the reductions in fatty acid value of paddy with 15.1% moisture, respectively, stored in 98, 95 and 90% nitrogen with continuous filling pattern for 18 months were 8.0, 6.6 and 5.7 and likewise, the reductions in fatty acid value of paddy with 15.1% moisture, respectively, stored in 98, 95 and 90% nitrogen with alternate filling pattern for 18 months were 4.2, 4.6 and 4.2.

3. After six months of CA storage with 98, 95 and 90% nitrogen, the paddies were unsealed for alternate N_2-CA storage, and the increases in fatty acid value of paddy were less than that of the contrast sample, which meant unsealing after N_2-CA storage at 25ºC had no influence on the fatty acid value of paddy.

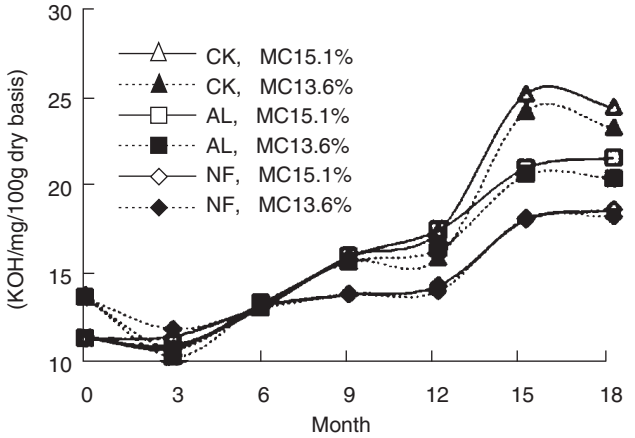

Fig. 8. Effect of filling patterns of 98% nitrogen on the fatty acid value of paddy at 20ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

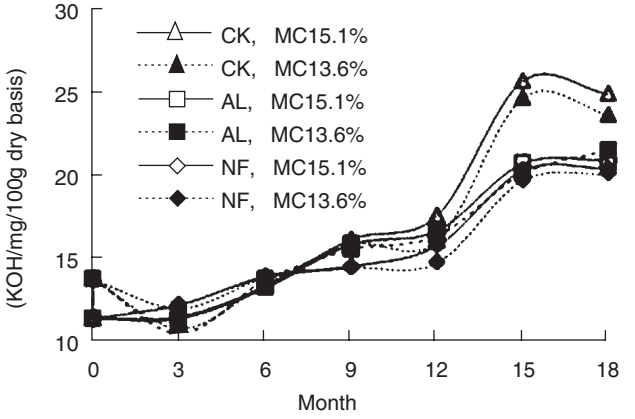

Fig. 9. Effect of filling patterns of 95% nitrogen on the fatty acid value of paddy at 20ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

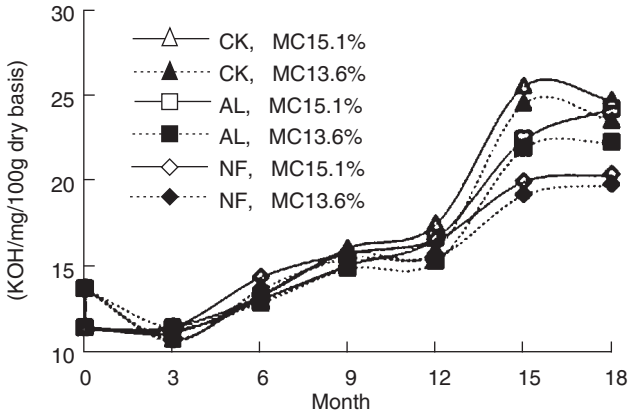

Fig. 10. Effect of filling patterns of 90% nitrogen on the fatty acid value of paddy at 20ºC ('NF', maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly hereinafter)

Effect of nitrogen filling patterns on the fatty acid value of paddy at 20ºC

The Figs 8–10 showed that the results obtained at 20ºC remained unchanged in comparison with those obtained at 30ºC and 25ºC.

Analysis on changes in fatty acid value of paddy under different conditions

Comparison of fatty acid value changes between N_2-CA storages and the contrast experiment

The CA storage with 98% nitrogen for 12 months could effectively delay the increase in fatty acid value of paddy (Fig.11); the effect of 90% nitrogen was comparatively poor; and alternately N_2-CA storage at 20ºC had nearly no effect on delaying the increase in fatty acid value of paddy.

CA storage with 98% nitrogen for 18 months could effectively delay the increase in fatty acid value of paddy (Fig. 12); the effect of 95% nitrogen

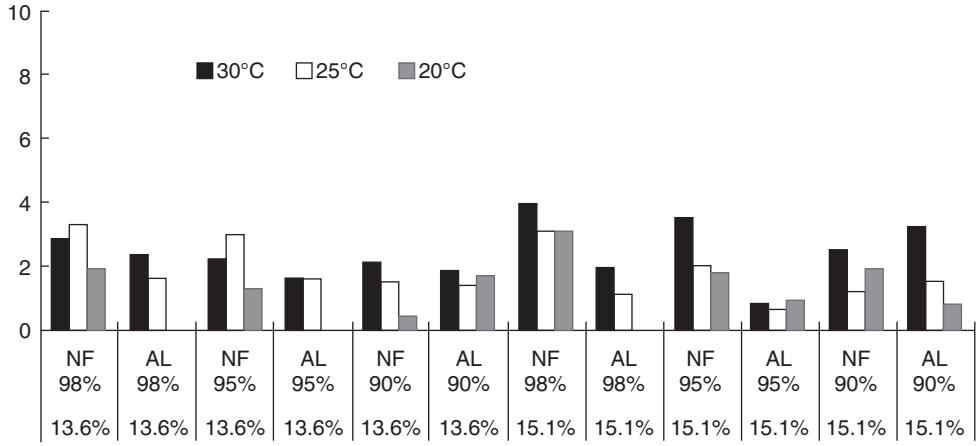

Fig. 11. Comparison of fatty acid value reductions between N_2-CA storages and the contrast experiment (12 months)

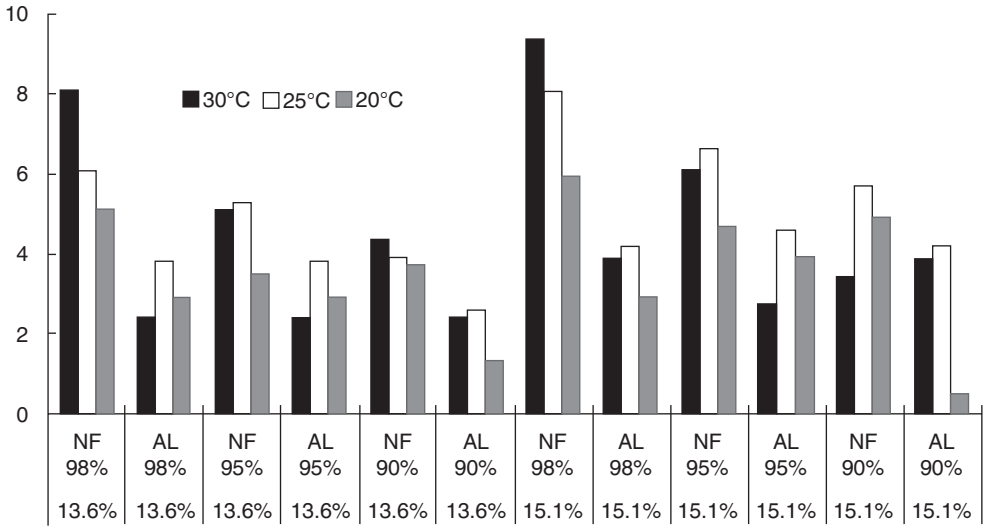

Fig. 12. Comparison of fatty acid value reductions between N_2-CA storages and the contrast experiment (18 months)

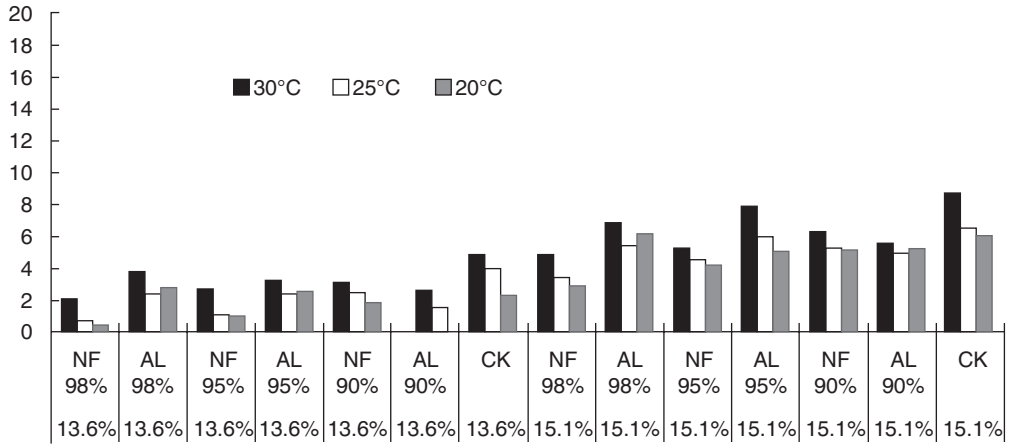

Fig. 13. Increases in fatty acid value of paddy stored under storage conditions (12 months) (‘NF’, maintaining at a certain nitrogen concentration; AL filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling nitrogen (similarly)

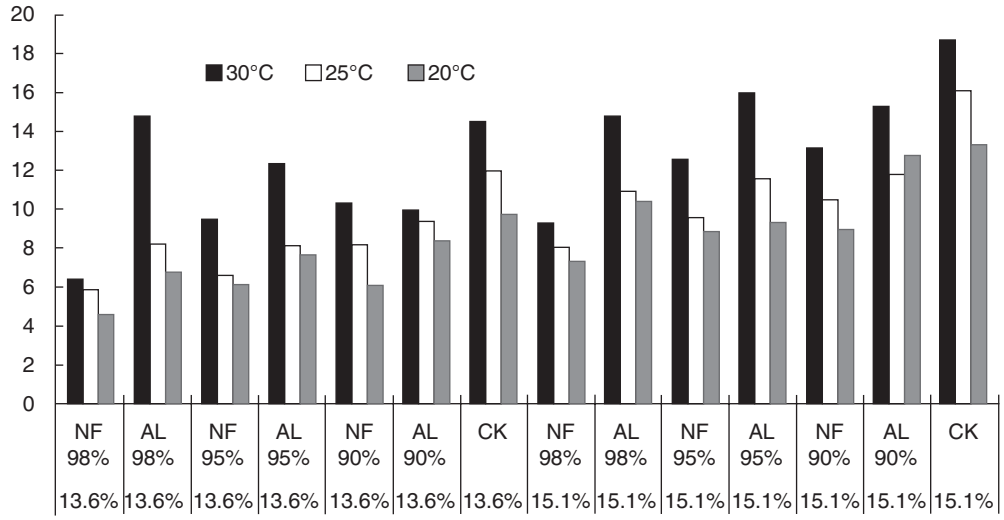

Fig. 14. Increases in fatty acid value of paddy stored under storage conditions (18 months)

was comparatively poor; and alternate filling of 90% nitrogen at 20ºC had nearly no effect on delaying the increase in fatty acid value of paddy.

Comparison of fatty acid value increase between N_2-CA and temperature control storages

In the case of temperature control storage, the fatty acid value of paddy with 13.6% moisture stored at 20ºC for 12 months (Fig. 13) increased by 2.3, and other six ways to achieve the same effect includes, CA storage by continuously filling 98% nitrogen at 30ºC; CA storage by continuously filling 95% or 98% nitrogen at 25ºC; CA storage by continuously filling 95% or 98% nitrogen at 20ºC; and CA storage with alternately filling 98% nitrogen at 20ºC. Similarly, suitable storage patterns can be freely chosen for warehouses in terms of different targets.

As per Fig.14, in the case of CA storage by continuously filling 95% nitrogen, the fatty acid value of paddy with 13.6% moisture stored at 25ºC for 18 months increased by 6.7; and other four ways to achieve the same effect includes, CA storage by continuously filling 98% nitrogen at 20ºC, 25ºC or 30ºC; and CA storage by continuously filling 90% nitrogen at 20ºC. Similarly, suitable storage patterns can be freely chosen for warehouses in terms of different targets.

CONCLUSION

1. At 20-30ºC, CA storages by either continuously or alternately filling nitrogen above 90% could delay the increase in fatty acid value of paddy, in which the most effective pattern is CA storages by continuously filling nitrogen above 95% at 30ºC, while the most ineffective one is CA storages by alternately filling nitrogen above 90% at 20ºC.
2. Compared with alternate N_2-CA storage, continuous

N_2-CA storage performed better in delaying the increase in fatty acid value of paddy.

3. Unsealing after N_2-CA storage had no influence on the fatty acid value of paddy.
4. These above results provide granaries with basic data to select appropriate storage methods depending on the target increase of fatty acid value of paddy.

REFERENCE

GB/T5490-2010 Inspection of grain and oils-General rules.