Haojie L, Hao Z, Wufang, Xiaoping Y, Yongjian F, Qiang S, Juan Z (2016) Effect of controlled atmosphere with nitrogen (N_2-CA) on fatty acid value of maize (*Zea mays*) under different temperature conditions. Pp. 103–108. In: Navarro S, Jayas DS, Alagusundaram K, (Eds.) Proceedings of the 10th International Conference on Controlled Atmosphere and Fumigation in Stored Products (CAF2016), CAF Permanent Committee Secretariat, Winnipeg, Canada.

Effect of controlled atmosphere with nitrogen (N_2-CA) on fatty acid value of maize (*Zea mays*) under different temperature conditions

LI HAOJIE, ZHOU HAO, WUFANG, YAN XIAOPING, FENG YONGJIAN, SHENG QIANG*, ZHANG JUAN

Sinograin Chengdu Grain Storage Research Institute, Chengdu, P. R. China

ABSTRACT

An experiment was conducted 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 maize (*Zea mays* L.) with two m.c. (13.2%, 14.0%) stored at three temperatures (20ºC, 25ºC and 30ºC) and by continuous N_2-CA, alternate N_2-CA and conventional method for 18 months. Both continuous and alternate N_2-CA storages could delay the increase in fatty acid value of maize, and the effect of former was significantly higher than that of the latter; the fatty acid value of paddies remained the same after the application of N_2-CA had been removed. These results obtained have provided granaries with basic data to select the appropriate storage methods (temperature control, way of filling nitrogen and so on) depending on the target increase of fatty acid value as well as the moisture content of maize.

Key words: Alternate nitrogen storage, Controlled atmosphere, Fatty acid, Maize, Nitrogen, Storage

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 increasing in China; therefore, to deeply understand the effect of N_2-CA on the fatty acid value of maize, a series of simulation trials were carried out in actual warehouses to analyze the effect of different N_2-CA patterns on the fatty acid values of maize 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 conditions listed on Table.1.

*Corresponding author e-mail: *shengqiang983@163.com*

Experimental grain

Maize of the same breed growing at the same condition produced by Chongzhou Agricultural Industry Demonstration Park, Sichuan, was selected. After a natural drying processing, two kinds of maize with different m.c. (13.2% and 14.0%) were obtained and then stirred to mix well. Every experimental bottle (50 L) was filled with 20 kg of each kind of maize.

Experimental method

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

Nitrogen filling

Experimental nitrogen concentrations, respectively, were 98%, 95% and 90%. First, 99.99% nitrogen was filled till the nitrogen concentration reached the target, and then 98%, 95% and 90% standard mix gas (composed of nitrogen and oxygen) were filled, respectively, through micro- airflow to maintain the

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

Grain	Moisture	Temperature	Nitrogen concentration	Filling pattern	Inspection frequency
Maize	13.2% 14.0%	20ºC 25ºC 30ºC	98% 95% 90%	Continuous N_2-CA Alternate N_2-CA	Sample every three month and inspect fatty acid Value

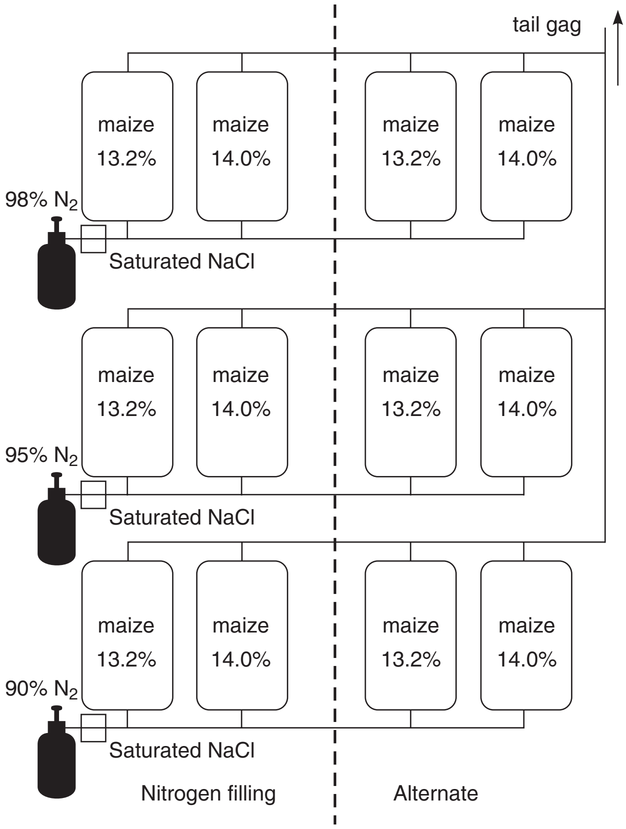

Fig. 1. Presentation of nitrogen filling experiment

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 first 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 hial 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 maize in accordance with the *General Rules of Inspecting Grain, Oilseeds and Vegetable Oils* (*GB/T 5490-2010*).

RESULTS AND ANALYSIS

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

Fig. 2, 3 and 4 showed that at 30ºC:

1. CA storage with 98%, 95% and 90% nitrogen could effectively delay the increase in fatty acid value of maize. After 15 months storage, the fatty acid value of the contrast sample exceeded 78 mg KOH/100 g. According to *GB/T 20570-2015 Guidelines for Evaluation of Maize Storage Character*, the contrast sample should not be stored. However, maize with CA storage did not exceed this limit.
2. After six months of CA storage with 98%, 95% and 90% nitrogen, the maize were unsealed for alternate N_2-CA storage, and the increases in fatty acid value of maize were less than that of the contrast sample, which meant unsealing after N_2-CA storage had no influence on the fatty acid value of maize.

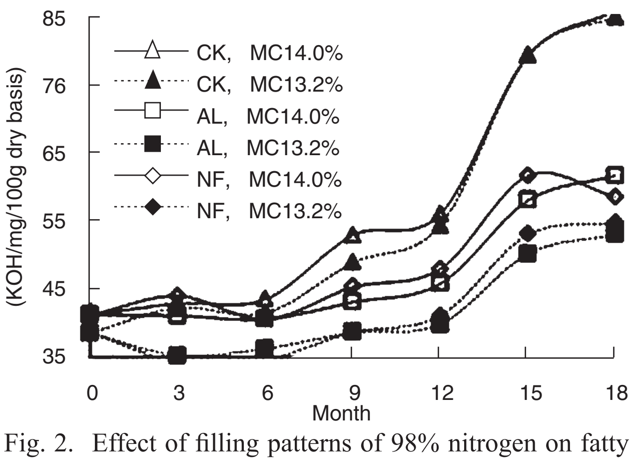

Fig. 2. Effect of filling patterns of 98% nitrogen on fatty acid value of maize at 30ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

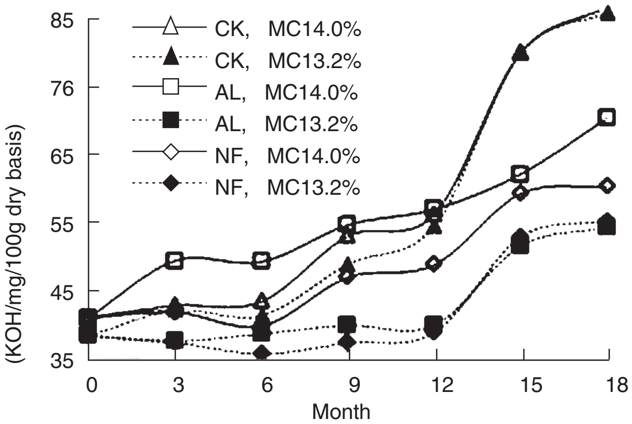

Fig. 3. Effect of filling patterns of 95% nitrogen on fatty acid value of maize at 30ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

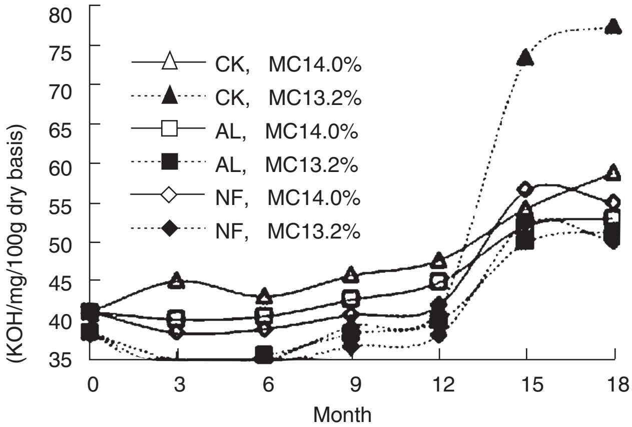

Fig. 5. Effect of filling patterns of 98% nitrogen on fatty acid value of maize at 25ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

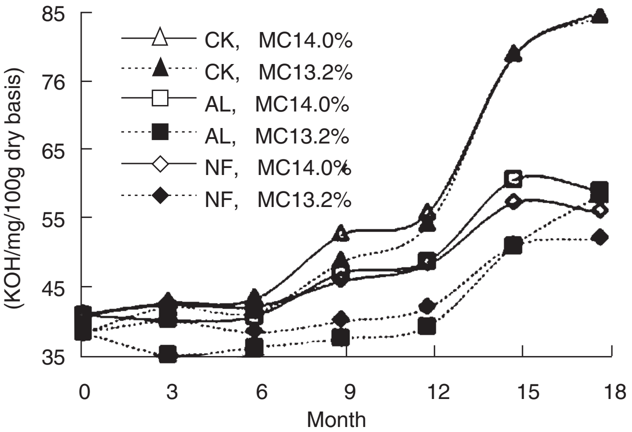

Fig. 4. Effect of filling patterns of 90% nitrogen on fatty acid value of maize at 30ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

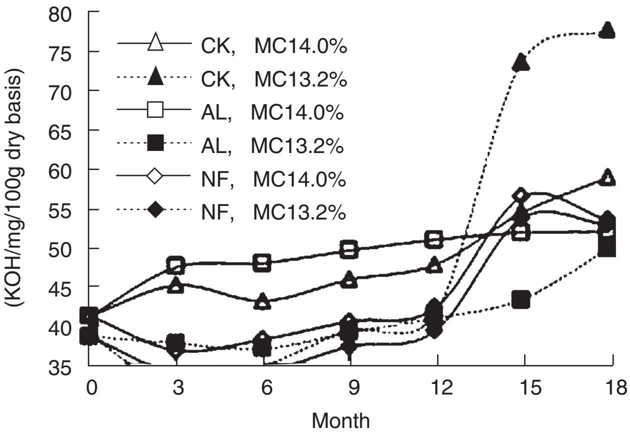

Fig. 6. Effect of filling patterns of 95% nitrogen on fatty acid value of maize at 25ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

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

Fig. 5, 6 and 7 showed that at 25ºC:

1. The CA storage with 98%, 95% and 90% nitrogen could effectively delay the increase in fatty acid value of maize, and higher nitrogen concentration performed better. For instance: (i) compared with the conventional storage, the reductions in fatty acid value of maize with 13.2% moisture, respectively, stored in 98%, 95% and 90% nitrogen with continuous filling pattern for 12 months were 3.3, 2.2 and 0; and likewise; and (ii) compared with the conventional storage, the reductions in fatty acid value of maize with 14.0% moisture, respectively, stored in 98%, 95% and 90% nitrogen with continuous filling pattern for 12 months were 5.7, 5.5 and 2.3. 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 maize with 13.2% moisture respectively stored in 98%, 95% nitrogen with continuous filling pattern for 12 months were 3.3 and 2.2; for alternate filling pattern, the reductions with 13.2% moisture,

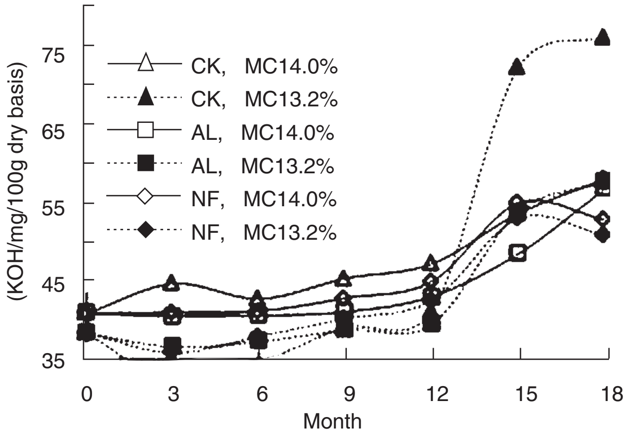

Fig. 7. Effect of filling patterns of 90% nitrogen on fatty acid value of maize at 25ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

respectively, stored in 98% and 95% nitrogen for 12 months were 1.5 and 0.6; the reductions in fatty acid value of maize with 14.0% moisture, respectively, stored in 98% and 95% nitrogen with continuous filling pattern for 18 months were 5.7 and 5.5; for alternate filling pattern, the reductions with 14.0% moisture, respectively, stored in 98% and 95% nitrogen for 18 months were 2.8 and 0.

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

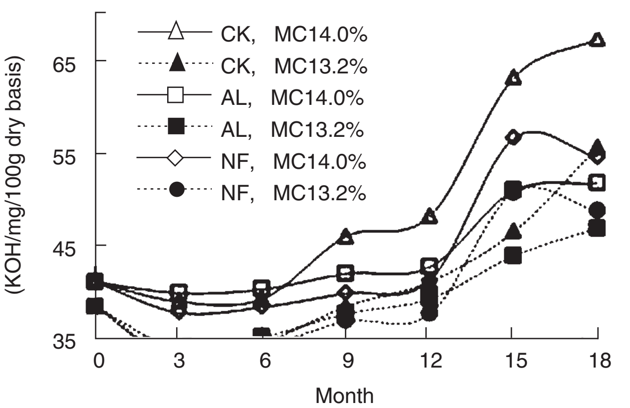

Fig. 8. Effect of filling patterns of 98% nitrogen on fatty acid value of maize at 20ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

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

The Figs.8–10 showed that the results obtained at 20ºC remained unchanged in comparison with those obtained at 30ºC and 25ºC. The CA storage with nitrogen could effectively delay the increase in fatty acid value of maize, and higher nitrogen concentration performed better. And continuous and alternate N_2-CA storages with 98% can delay the increase in fatty acid value of maize, and the former's effect was significantly higher than that of the latter; continuous

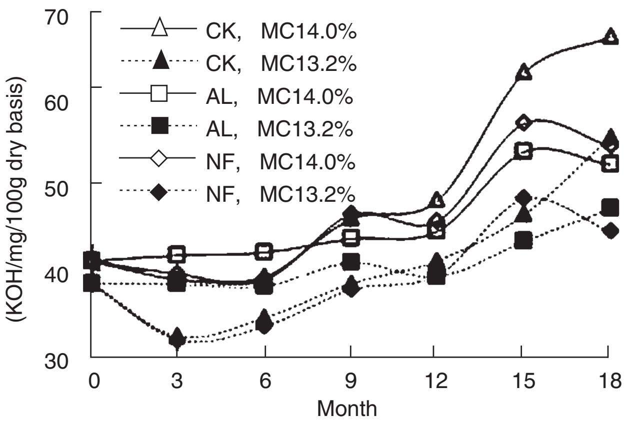

Fig. 9. Effect of filling patterns of 95% nitrogen on fatty acid value of maize at 20ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

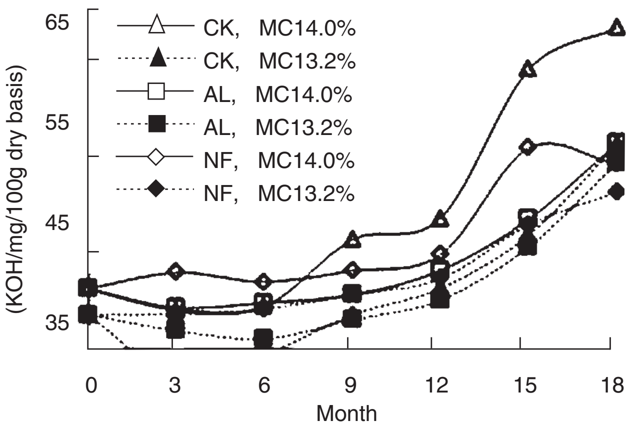

Fig. 10. Effect of filling patterns of 90% nitrogen on fatty acid value of maize at 20ºC (NF, maintaining at a certain nitrogen concentration; AL, filling nitrogen for six months, conventionally storing for six months and then refilling nitrogen for six months; and CK, conventional storage without filling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

and alternate N_2-CA storages at 20ºC and with 95% and 90% nitrogen concentration showed nearly the same delaying effect. This may be related with the temperature. After six months of CA storage with 98%, 95% and 90% nitrogen, the maize were unsealed for alternate N_2-CA storage, and the increases in fatty acid value of maize were less than that of the contrast sample, which meant unsealing after N_2-CA storage had no influence on the fatty acid value of maize.

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

Comparison of fatty acid value changes between N_2-CA storages and the contrast experiment: As per Fig. 11, CA storage with 98% and 95% nitrogen for 12 months could effectively delay the increase in fatty acid value of maize, especially in 30ºC condition; when the temperature was 20ºC, the delaying effect of CA-N_2 was not obvious. Continuous and alternate N_2-CA storages at 20ºC and with 95% and 90% nitrogen concentration to delay fatty acid value increasing had no significant difference. The m.c. had influence on nitrogen delaying increase in fatty acid value.

According to Fig.12, CA storage with 98% and 95% nitrogen for 18 months could effectively delay the increase in fatty acid value of maize, especially in 30ºC condition; when the temperature was 20ºC, the delaying effect of CA-N_2 was not obvious.

Continuous and alternate N_2-CA storages at 20ºC and with 95% and 90% nitrogen concentration to delay fatty acid value increasing had no significant difference. Moisture content had influence on nitrogen delaying

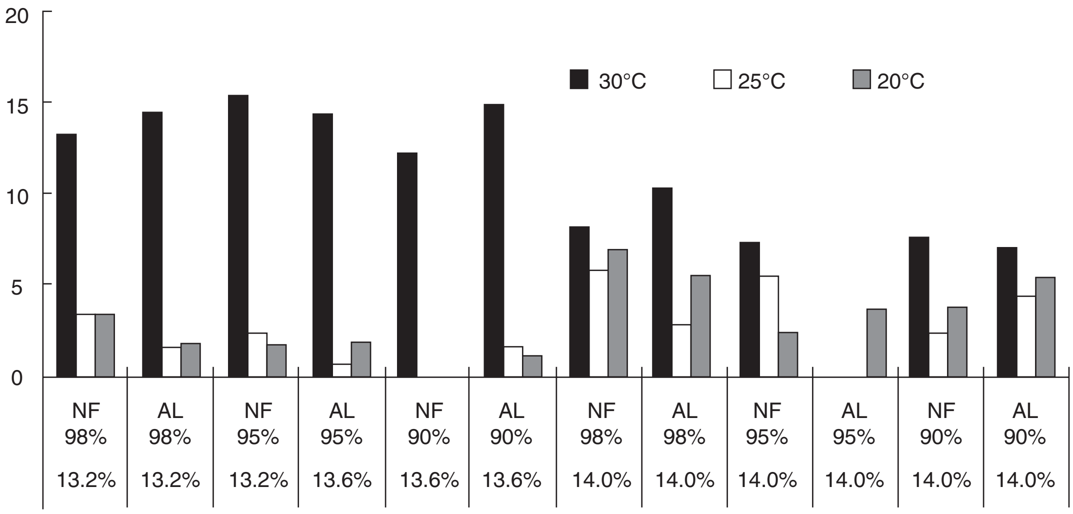

Fig. 11. Comparison of fatty acid value reductions between N_2-CA storages and the contrast experiment (12 months)

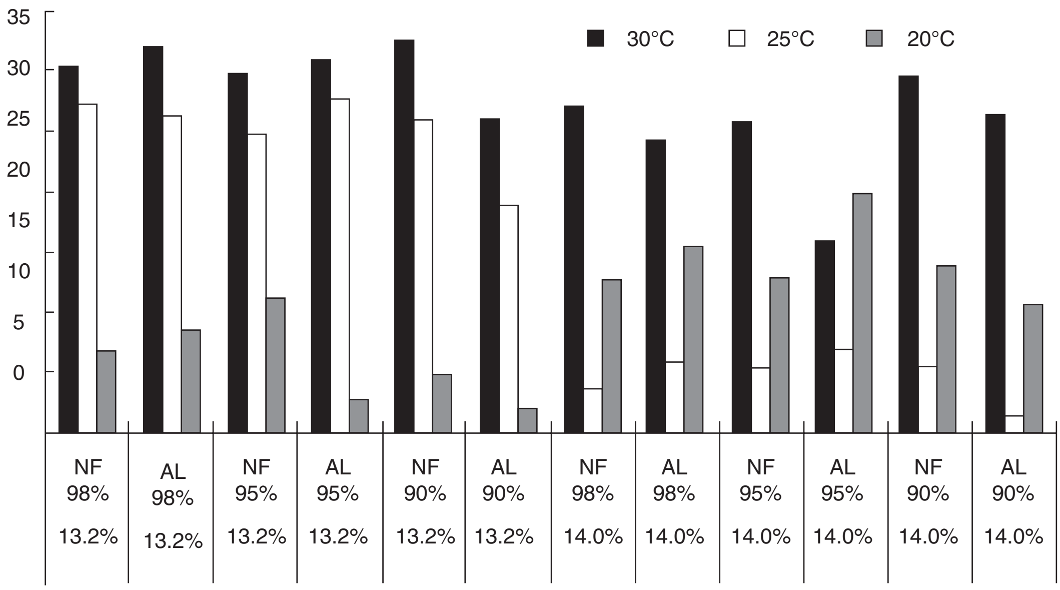

Fig. 12. Comparison of fatty acid value reductions between N_2-CA storages and the contrast experiment (18 months)

increase in fatty acid value.

Comparison of fatty acid value increase between N_2-CA and temperature control storages: As per Fig.13, in the case of temperature control storage, the fatty acid value of maize with 13.2% moisture stored at 20ºC for 12 months increased by 2.6, and other 15 ways to achieve the same effect includes, CA storage by continuous and alternate filling 98% nitrogen at 20ºC, 25ºC and 30ºC; CA storage by continuous and alternate filling 95% nitrogen at 20ºC, 25ºC and 30ºC; CA storage by alternate filling 90% nitrogen at 20ºC, 25ºC and 30ºC. Similarly, suitable storage patterns can be freely chosen for warehouses in terms of different targets.

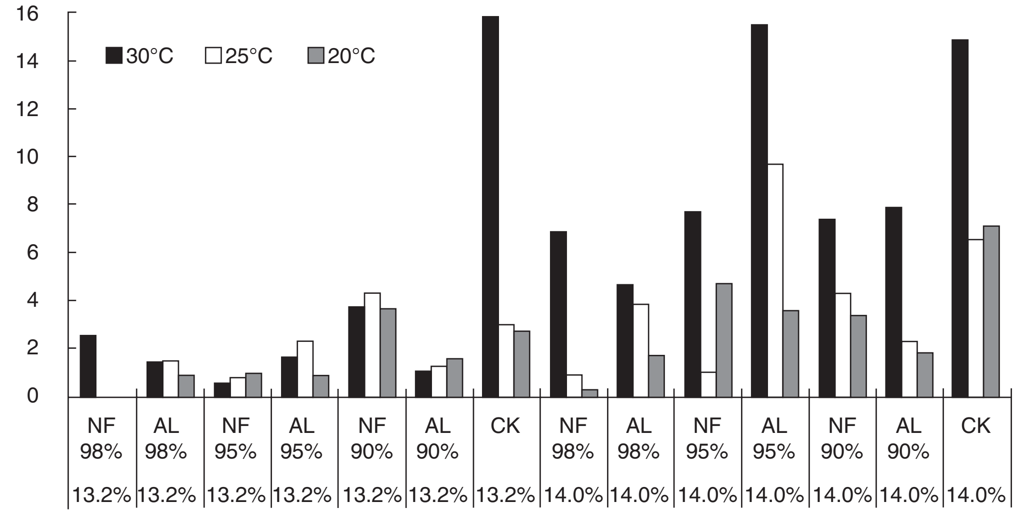

Fig. 13. Increases in fatty acid value of maize stored under different storage conditions (12 months)

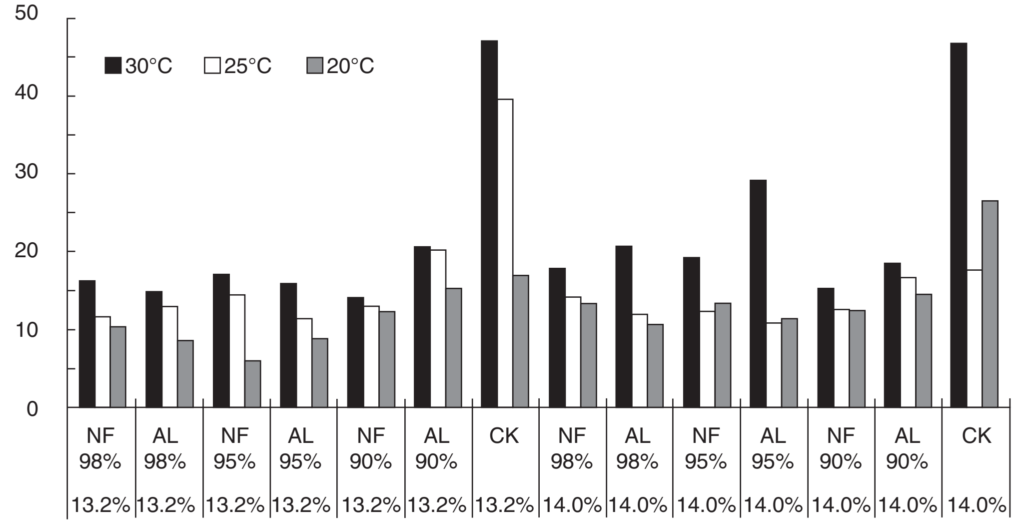

Fig. 14. Increases in fatty acid value of maize stored under different storage conditions (18 months)

As per Fig.14, in the case of CA storage by alternately filling 98% nitrogen, the fatty acid value of paddy with 13.2% moisture stored at 25ºC for 18 months increased by 12.8; and other ways to achieve the same effect include, CA storage by continuously filling 98% nitrogen at 20ºC and 25ºC, CA storage by alternately filling 98% nitrogen at 20ºC, CA storage by continuously or alternately filling 95% at 20ºC, and CA storage by continuously filling 90% at 20ºC. Similarly, suitable storage patterns can be freely chosen for warehouses in terms of different targets.

CONCLUSION

On the basis of results, we may conclude that: (i) At 20-30ºC, CA storages by either continuously or alternately filling nitrogen above 90% could delay the increase in fatty acid value of maize; (ii) compared with alternate N_2-CA storage, continuous N_2-CA storage performed better in delaying the increase in fatty acid value of maize; (iii) unsealing after N_2-CA storage had no influence on the fatty acid value of maize; and (iv) these results provide granaries with basic data to select appropriate storage methods depending on the target increase of fatty acid value of paddy.

REFERENCES

GB/T5490-(2010) Inspection of Grain and Oils-General Rules.

GB/T20570-(2006) Guidelines for Evaluation of Maize Storage Character.