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The influence of storing high moisture-content rough rice on milling quality

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The influence of storing high-moisture content rough rice on milling quality

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ABSTRACT

The objective of this research was to determine the influence on drying characteristics of storing high-moisture content (MC) rough rice under various conditions and durations before drying. Two cultivars of rice, 'Bengal', a medium-grain cultivar, and 'Cypress', a long-grain cultivar, were used. The MC of 'Bengal' was 24.8%[1] and that of 'Cypress' was 20.4% at harvest. Immediately after harvest, drying runs were performed with samples of both cultivars under two drying air conditions: one at 51.7°C (125°F) and 25% relative humidity (RH), and the other at 60°C (140°F) and 17% RH. Storage treatments using the high MC rice were also initiated immediately after harvest. Both cultivars of rough rice were stored for one month (i.e., 27 d) and three months (i.e., 76 d) in either a walk-in freezer at –9°C (15°F), a household refrigerator at 3.5°C (38.3°F) or a walk-in cooler at 4°C (38.5°F). After one month and three months of storage, all samples were dried under the same two drying air conditions as at harvest. The head rice yield (HRY) was determined for all the dried samples. There were no differences in the HRYs of samples that were stored for one or three months and then dried and in those HRYs of samples dried immediately after harvest; this finding was consistent across the three storage temperatures for both cultivars. The trends in HRY reduction were similar to previously reported drying trials using these drying air conditions. This research indicates that it is possible to store rough rice at high MCs for up to three months under storage temperatures varying from –9°C to 4°C without affecting HRY.

* Julita M. Manski will graduate in November 2002 with a degree in food science and technology from the Wageningen University in the Netherlands.

§ Terry J. Siebenmorgen, faculty sponsor, is a professor in the Department of Food Science.

1 All moisture contents are expressed on a wet basis unless otherwise noted.

MEET THE STUDENT-AUTHOR

Julita Manski

Although I was born in Poland, I have lived in the Netherlands since I was four. After graduating from high school in 1997, I wanted to pursue a major in which science as well as engineering subjects were integrated. Food science and technology seemed the perfect major comprising my fields of interest. The only university in the Netherlands offering this major with a master's degree was in the small college town of Wageningen. Therefore, my decision to attend Wageningen University was easily made.

In addition to attending classes and labs during the first three years of the education, I was also involved in our Food Science Club. I have worked several part-time jobs throughout my college time as well. During the last two years, I was able to put my gained knowledge into practice by completing two theses in the field of process engineering.

Since internships are required in my major, during the fall of 2001 I had the opportunity to conduct an internship at the University of Arkansas. This internship was one of the best experiences of my college time. Both the research that I executed, and the experience of living in the USA were very instructive. I would like to take the opportunity to thank Dr. Terry Siebenmorgen for advising me during the research, and Jerry Fendley for helping me carry out the experiments. Further, I want to express my gratitude to every one that I met, for making my stay in Arkansas precious. Having been abroad has given me the chance to develop myself both professionally and personally.

In the summer of 2002 I will conduct a second internship. Arrangements are being made by H.J. Heinz Company in Pittsburgh, Penn., to work with the R&D department. I will graduate from Wageningen University in November 2002. After graduating, I hope to enroll in a Ph.D. program at a university in the USA.

INTRODUCTION

Immediately after harvest, on-farm and commercial rice driers as well as research laboratories conducting rice drying research face a busy drying season. All would benefit tremendously if the possibility existed to delay drying by storing rough rice at high MC for a period of time prior to drying. High-MC storage of rough rice under specified conditions could be a means to extend the drying season, provided the properties and thus the drying characteristics of the rice remain unchanged during storage.

Previous research has mainly focused on storing rough rice under different conditions varying from 2°C to 38°C after drying (Chrastil, 1990; Daniels et al., 1998; Kitamura et al., 1977; Pearce et al., 2001; Villareal et al., 1976). These studies showed that storage temperature had a significant effect on various rice quality indices. Daniels et al. (1998) showed that rice storage MC also played an influential role. The storage of rough rice at high MCs has received little attention.

MATERIALS AND METHODS

Harvest

Two cultivars of rice, 'Bengal' and 'Cypress', were harvested at the Rice Research and Extension Center, Stuttgart, Ark., in August 2001. Immediately after harvest, the rice was transported to the University of Arkansas Rice Processing Laboratory, Fayetteville, Ark., and cleaned using a Carter-Day Dockage tester (Carter-Day Co., Minneapolis, MN). Upon arrival at the lab, the MC of 'Bengal' was 24.8% and the MC of 'Cypress' was 20.4%. Bulk sample MCs were determined by drying 15 to 16 g of rough rice in a convection oven for 24 h at 130°C (Jindal and Siebenmorgen, 1987). Individual kernel MC measurements were performed using an individual kernel moisture meter (Model CTR-800 E, Shizuoka

Seiki Co., Ltd., Shizouka, Japan). After cleaning, samples of both cultivars were immediately dried and others were dried after certain storage durations.

Storage

Immediately after harvest, lots of 'Bengal' and 'Cypress' rough rice were placed in sealed plastic containers in one of three different storage environments represented by storage temperatures of –9°C (15°F), 3.5°C (38.3°F), and 4°C (38.5°F). The -9°C temperature was attained by placing containers in a walk-in freezer, that of 3.5°C was maintained in a household refrigerator, and that of 4°C was maintained in a walk-in cooler. It is to be noted that the original experimental design specified a higher temperature to be maintained in the refrigerator. However, controls were such that the average temperature was 3.5°C; thus the treatments in the walk-in cooler and refrigerator are included as essentially replications. From an economic point of view, the above-freezing conditions might be realizable for the industry to temporarily store rough rice. The -9°C storage condition, however, was included as a possible storage environment for research samples.

Each of the six sub-lots of rough rice (two cultivars x three storage environments) were stored in sealed plastic containers, each containing approximately 23 kg. The rice was stored for two durations, one month (27 d) and three months (76 d), in each of the three storage environments. After one month and three months of storage, approximately 8 kg of each of the six stored lots were taken out of the containers and equilibrated for 5 to 12 h at room temperature before drying.

The actual temperatures of the storage environments were monitored during the study and are shown in Fig. 1. The temperatures for the storage environments for the walk-in freezer (-9°C) and the walk-in cooler (4°C) were consistent during the storage duration. However, the temperature in the refrigerator (3.5°C) fluctuated due to the inability of the refrigerator to adjust to changes in ambient temperature; the average of temperature readings during the three month storage was 3.5°C.

Drying

Immediately after harvest, samples of both cultivars were dried using two air conditions. Both drying air conditions were chosen based on previous research (Fan et al., 2000). The first condition was 51.7°C and 25% relative humidity (RH) and is representative of actual conditions used in commercial drying. The resulting equilibrium moisture content (EMC) as predicted by the Chung equation was 7.3% (ASAE, 1998). The second condition was 60°C and 17% RH. This condition is at the upper extreme of commercial drier temperature levels, but was shown to have potential for use if combined with a tempering treatment (Cnossen and Siebenmorgen, 2000). The resulting EMC for the second drying air condition was 5.8%. These two conditions were used for all drying runs. Each drying run for a cultivar / drying air condition / storage duration / storage temperature was performed twice.

The first drying runs conducted immediately after harvest represent the drying characteristics of rice that was not stored prior to drying. These runs will be referred to as the drying runs of month 0. After one

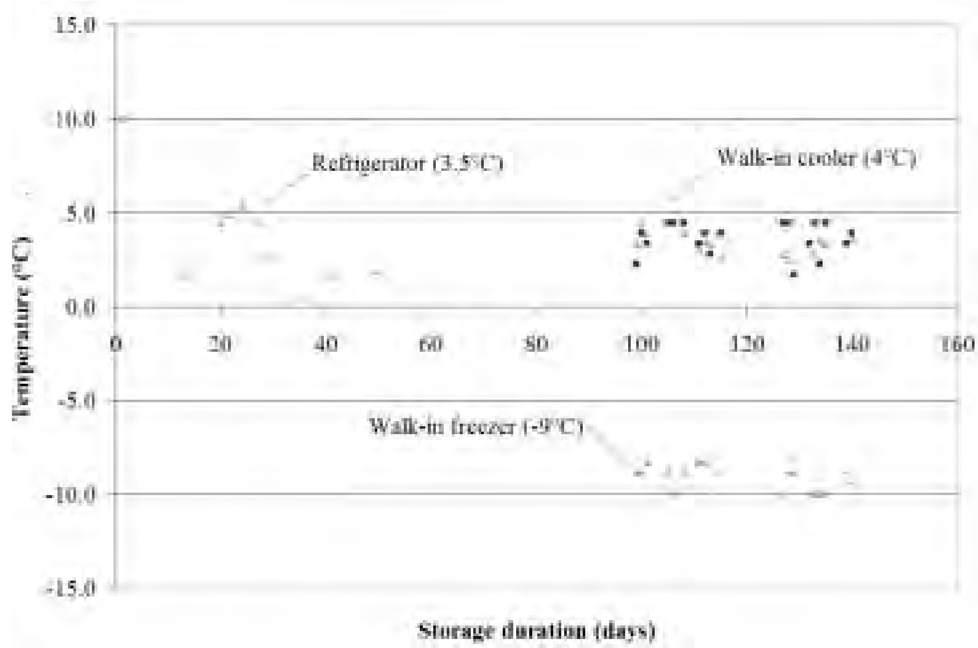

Fig. 1. Actual temperature histories of the three storage environments.

month and three months of storage, samples of the stored rough rice were equilibrated to a lab temperature of approximately 25°C and then dried under the same drying air conditions as month 0.

The drying air conditions were controlled by temperature and RH control units (Parameter Generation & Control, Inc.,-PG & C-Black Mountain, NC) and monitored by a Hygro-MZ dew-point monitor (General Eastern, Woburn, MA). Air from each PG&C unit was supplied to laboratory drying chambers, each consisting of 16 trays (15 ¥ 25 cm) with perforated bottoms. The 16 trays were arranged as two eight-tray sets. In each of the eight-tray sets, one tray was designated to be weighed at each defined drying duration to measure the weight loss due to drying. Each tray was filled with a uniform layer of approximately 110 g of rice. The drying durations for a drying run were 0, 10, 20, 30, 45, 60, 90, and 120 min. Drying durations were randomly assigned to trays to eliminate the influence of the location of a sample in the drying chamber. After a certain drying duration, paired trays from each eight-tray set were combined to form one rice sample for milling. After drying, the combined samples were immediately placed in a conditioning chamber (21°C, 48% RH) to cool and to slowly continue to dry to an MC of approximately 12.5%. This cooling is known to produce a reduction in HRY if a sufficient MC gradient is present in the kernel (Cnossen and Siebenmorgen, 2000). After conditioning for four to five days, the samples were stored in sealed plastic bags in a cooler at 4°C for one to two months prior to milling.

Milling

Upon removal from cold storage, samples were first equilibrated to room temperature before hulling and milling. Approximately 150 g of dried rough rice was hulled with a Satake Rice Machine (Satake Engineering Co., Ltd., Tokyo, Japan). The resultant brown rice was milled with a laboratory miller (McGill No. 2, Rapsco, Brookshire, TX). A weight of 1.5 kg was placed on the lever arm of the mill 15 cm from the centerline of the mill chamber. All samples were milled for 30 s. The milled samples were aspirated with a South Dakota Seed Blower (Seedburo, Chicago, IL) for 30-60 s to clean the rice by removing any bran that was left after milling.

The weight of head rice was determined with a Graincheck 2312 Analyzer (Foss Tecator, Höganäs, Sweden). Head rice comprises kernels that are at least three-fourths of the original kernel length. HRY was then calculated as the weight percentage of rough rice that remained as head rice after milling.

For a selection of samples, the degree of milling (DOM) of the head rice was determined with a milling meter (Satake MM 1B, Satake Engineering Co., Ltd., Tokyo, Japan). Since the rice samples were not physically separated into head rice and broken kernels by the Graincheck, the head rice from the samples was separated with a double-tray shaker table (Grainman, Grain Machinery Mfg., Miami, FL) before determining the DOM. The range of DOM for 'Bengal' head rice was 73 to 90 with an average of 82. 'Cypress' head rice showed a higher DOM range of 99 to 115 with an average of 102.

RESULTS AND DISCUSSION

Overall Observation

Physical differences were observed between the rough rice samples that had been stored before drying and those that were dried immediately after harvest. The rough rice held at –9°C showed ice crystals between the rice kernels after three months of storage. However, no ice crystals were observed after one month of storage. Since 'Bengal' was stored at a high MC of 24.8%, visible mold growth was expected and confirmed after one and three months of storage at 3.5°C and at 4°C. At the storage temperature of –9°C no mold growth was found on 'Bengal' or 'Cypress' at any storage duration.

The MC of the stored rice samples was measured immediately after each storage duration. The MC of both cultivars increased only slightly during storage: the maximum increase in MC for 'Bengal' was 0.5 percentage points and for 'Cypress' 0.9 percentage points. Immediately after harvest and after one and three months of storage, individual kernel MC measurements were performed. The expectation was that the MC distribution would become narrower after storage. However, there was no observable difference between the kernel MC distribution of the freshly harvested rice and the stored rice. These results were consistent for both cultivars stored at all temperatures.

Head Rice Yield (HRY)

HRY trends of 'Bengal' and 'Cypress' samples that were dried immediately after harvest (Fig. 2) closely resembled those of previous research (Fan et al., 2000). When drying under the air condition of 51.7°C and 25% RH, the HRY for 'Cypress' remained almost constant, even for extended drying durations. The HRY of 'Bengal' showed a decrease for this same air condition as the drying duration exceeded 20 min before cooling to 21°C. Since 'Bengal' is a medium-grain rice cultivar, its features include a short and thick kernel. Previous research has shown that this type of kernel is more susceptible to fissuring after drying than long-grain cultivars such as 'Cypress' that comprise long, thin kernels (Fan et al.

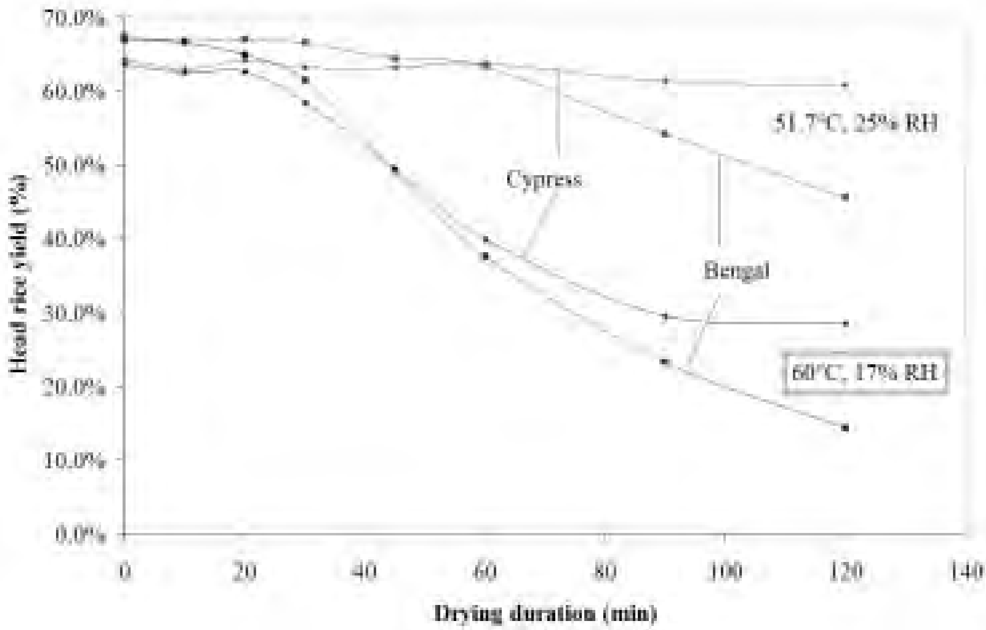

Fig. 2. Head rice yields for 'Bengal' and 'Cypress' versus drying duration, for the case in which drying was performed immediately after harvest (month 0) under the two indicated drying air conditions.

2000; Jindal and Siebenmorgen, 1994; Kunze, 1983). The more severe drying air condition of 60°C and 17% RH caused a greater decrease in HRY for both 'Bengal' and 'Cypress' than did the lower-temperature drying condition. The greater decrease of 'Bengal' HRY over that of 'Cypress' was more apparent after 20 min of drying for both drying air conditions. Further, when drying 'Cypress' under the severe drying air condition of 60°C and 17% RH, the HRY approached a constant value after 90 min of drying regardless of further increase in drying duration. The results in Fig. 2 are the reference values to compare HRYs of samples that had been stored prior to drying.

The HRY trends of the rice samples that had been stored for one and three months at the three storage environments of –9°C, 3.5°C, and 4°C before drying were similar to the HRY response of the month 0 samples. This was observed for both cultivars (Figs. 3 and 4). The storage durations did not influence the HRY response of the samples, especially in the first 30 min of drying under both drying air conditions. Since drying durations of 20 to 40 min are common in the industry, these results are very promising in regard to possible commercial application.

In order to compare the HRY responses of the three storage environments, the average HRYs over the three storage durations were computed for each storage environment (Fig. 5). It is very clear that there were no differences in HRY trends observable between the three storage environments. Even freezing of rough rice for up to three months and then drying did not affect the HRY compared to rice that had been dried immediately after harvest. The physical degradations that were observed during storage, such as ice crystals in the frozen samples and growth of mold in the higher temperature storage environments, did not apparently influence the HRY of the rice when dried.

This research shows that high-MC rough rice can be stored for up to three months at temperatures varying from below to just above freezing without affecting HRY when dried. Although physical changes such as mold growth did occur during storage of the high MC rough rice, there was no apparent effect on milling quality due to the mold growth. For commercial driers this finding indicates that the drying season could possibly be extended, which would provide more flexibility. On a laboratory scale, the findings indicate that drying trials do not have to be conducted immediately after the harvest of rice but can be performed after storing temporarily in cold storage. It is emphasized that further research focusing on the effects of such storage practices on other quality factors is required before industrial implementation.

ACKNOWLEDGMENTS

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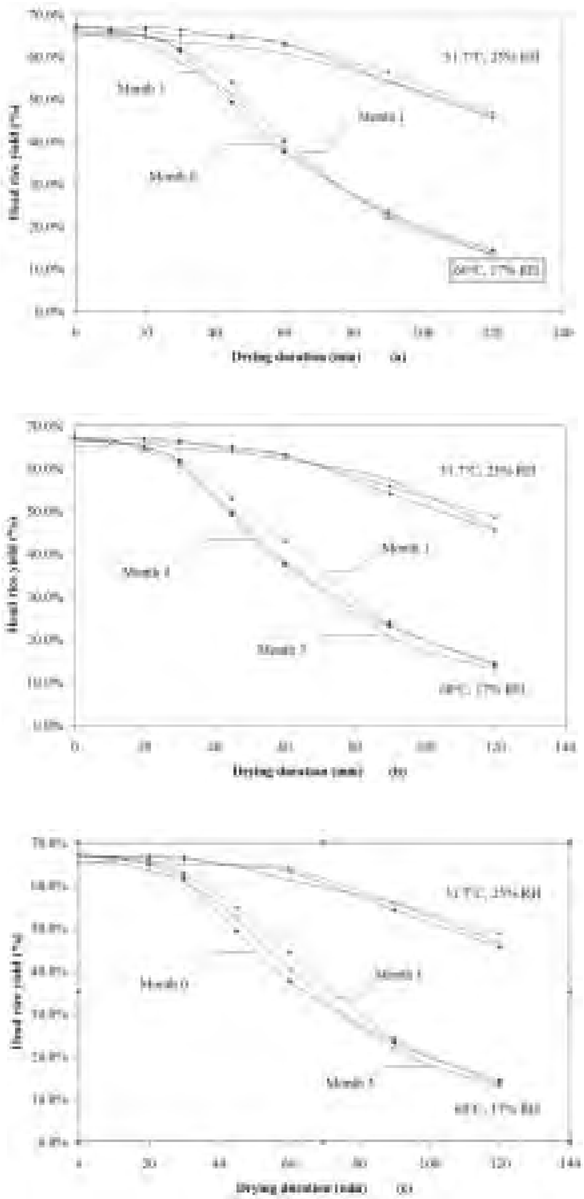

Fig. 3. Head-rice yield response of 'Bengal' stored in a freezer at –9°C (a), in a cooler at 4°C (b), and in a refrigerator at 3.5°C (c) for the indicated durations before drying with the two indicated drying air conditions versus the drying duration.

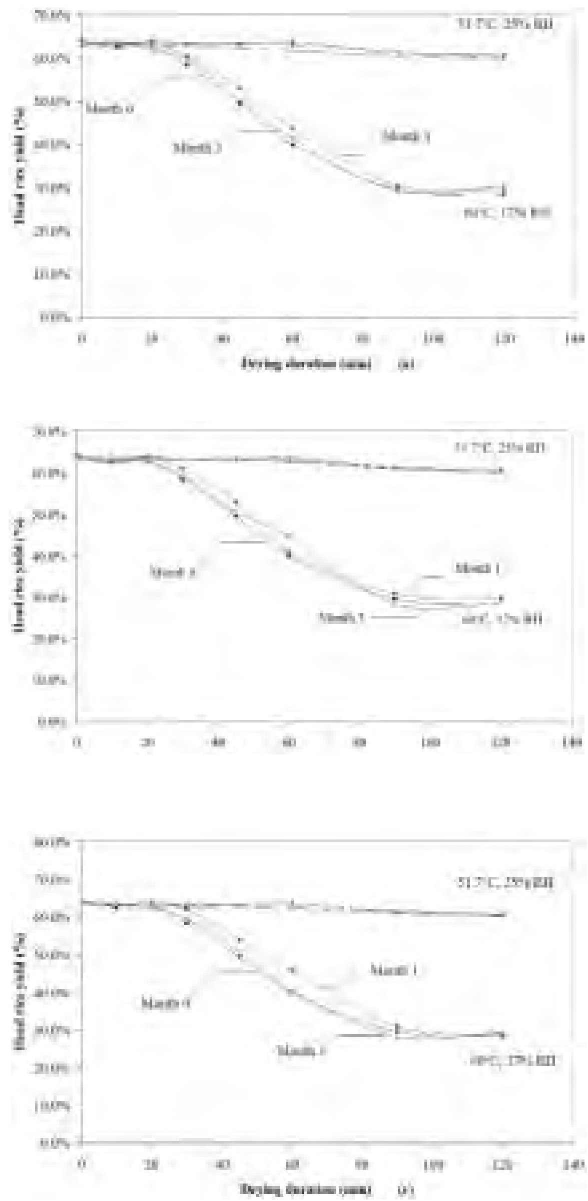

Fig. 4. Head rice yield response of 'Cypress' stored in a freezer at –9°C (a), in a cooler at 4°C (b), and in a refrigerator at 3.5°C (c) for the indicated durations before drying with the two indicated drying air conditions versus the drying duration.

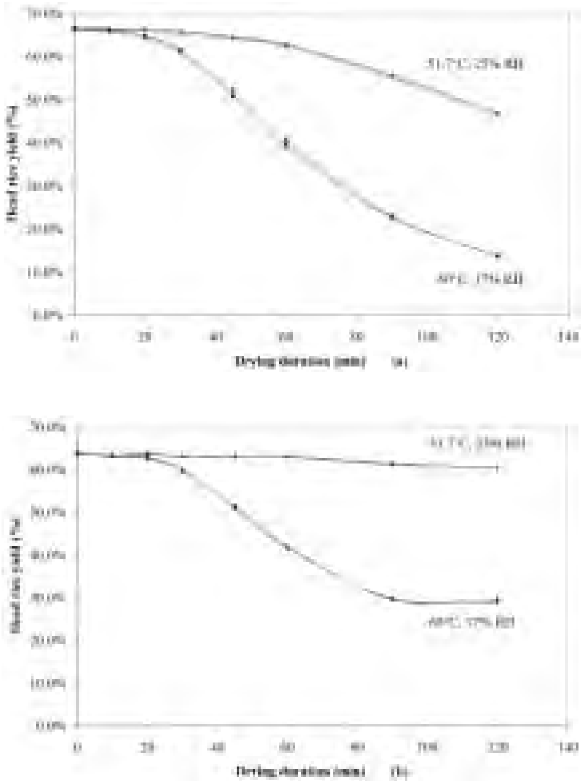

Fig. 5. Average head rice yield response over the storage durations of 'Bengal' (a) and 'Cypress' (b). The various curves represent the three storage environments of a walk-in freezer (-9°C), a refrigerator (3.5°C), and a walk-in cooler (4°C).

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