International Journal of Agricultural Technology 2022Vol. 18(2):795-808
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Effect of drying methods during priming on quality and longevity of rice seeds

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Sangkrabun, P. and Sikhao, P. (2022). Effect of drying methods during priming on quality and longevity of rice seeds. International Journal of Agricultural Technology 18(2):795-808.

Abstract The best suitable drying method for primed Khao Dawk Mali 105 rice seeds was used a hot air oven at 30 ℃ for 36 h and stored them in the uncontrolled environment. There was resulted to be lowest moisture, highest germination percentage and germination index for primed seeds. This method can keep the moisture in rice seeds low, reduce the process of decaying and extend the longevity and quality of primed rice seeds.

Keywords: Khao Dawk Mali 105 rice seed, Drying method, Seed longevity

Introduction

Rice (*Oryza sativa*) is a plant species belongs to family Poaceae which mostly found in Asia. Rice is a cereal crop that people favorably consume, especially Asian people. In Thailand, there is the long history of rice consumption and is the top country in the world to export. Refer to the data from Department of International Trade Promotion, Thailand export rice with amount of 11.08 million tons (Department of International Trade Promotion, Ministry of commerce, 2018). The problem is normally found in rice planting In Thailand, diseases and pests destroy products which decrease of product quality including the inappropriate seed storage in a long time leasing to deteriorated seed, and low germination rate. The popular way to solve the problem of low-quality seed is seed priming method which leads to get the better quality of seeds by soaking seeds in water with appropriate temperature and time, reduce moisture into the previous level before priming the seed. This is to be priming the seeds at the first level of germination, but not in the stage which radicle emerges out from the seed coat (McDonald, 2000). When that seed is planted, seed will quickly germinate because there is some extent of physiology activity inside that seed. (Fakthongphan, 2016). Moreover, seed priming will be helped to increase germination rate and vigour of seeds which

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leads to increase the seed endurance to environment in a farm, including increasing of products in the farm (Santipracha, 1987). There are a lot of substances to be priming the seed germination which are synthetic substance and natural substance. Jiemjan and Thiphinkong (2019) stated that seed germination by using fermented pig placenta extract found that fermented pig placenta extract in ratio of 1:30 leaded to get higher germination percentage and germination index. In addition, Ruchiracak *et al*. (2010) studied the method to increase seed quality by using fermented pig placenta extract and found that 50 times diluted extract made higher germination percentage of Chai-Nat 1 rice seeds and quickly germinated. Seed priming is easy to do, utilizes low cost and has no remaining of poisonous substance to the environment (Siri, 2015). In this paper, researcher is interested to use fermented bio-extract as it is easy to find, cheap and no remaining in the planting area. Fermented bio-extract is the extract from a part of organisms such as vegetables, fruits and animals to ferment with sugar in the anaerobic condition which consists of nutritional microorganisms and many types of organic substance which are good for plants. However, the purpose of seed priming is to reduce the seed moisture to be closed to the previous moisture level that is difficult condition. Poor moisture reduction affects to deterioration among the storage as seed cannot store in a long time which also affects low seed quality and poor products. From the above problem, the research was aimed to study the appropriate method to drying the Khao Dawk Mali 105 primed rice seed with fermented pig placenta extract for keeping a long shelf-life of primed seeds.

Materials and methods

This research was experimented by using 2 factors factorial in completely randomized design which factor A was seed drying method and factor B was storage condition. Khao Dawk Mali 105 rice seeds were soaked in fermented pig placenta extract with ratio of 1:30 (extract: distilled water) at 18^{o}C for 48 hours, then the Khao Dawk Mali 105 rice seeds were washed through the water and dab, followed by heating in hot air oven for drying at different temperature and time; 25^{o}C for 48 hours, 30^{o}C for 36 hours, 35^{o}C for 24 hours and 40^{o}C for 12 hours. The non-primed seeds were served as a control. All seed drying treatments including control treatment were stored under control (15 ℃, 20% relative humidity) and ambient (approximately 30 ℃, 65% relative humidity) conditions for 5 months. The samples were collected at 0, 1, 3 and 5 months to test the quality of seeds as seed moisture content, seed water activity, germination percentage and germination index.

Seed moisture content

Seed moisture content were determined by hot air oven method. The aluminum can was weighted with its lid and recorded the initial weigh (before heat in hot air oven). The 5-10g of sample (Khao Dawk Mali 105) was then weighted and recorded in each treatment with 4 replications. After that, the aluminum can with each sample was heated in the hot air oven at 105^{o}C for 24 hours by open can lid (ISTA, 2019). When the heating was completed, the aluminum can was taken out of the hot air oven and closed with its lid, were then put into the desiccator for 30 minutes. Finally, the aluminum can were weighed with the sample inside. The seed moisture content was calculated by below formula:

$$\%\text{moisture} = \left[\frac{\text{Initial weight (before heat)} - \text{Final weight (after heat)}}{\text{Initial weight (before heat)}}\right] \times 100$$

Seed water activity

Water activity is performed by using RR Moisture (Brand: RHINO, model: HC2-AW-USB-SW) which is the moisture determination method by water activity. Reduced-moist sample (seed) is put in the probe, then placed the probe with sample in sample holder and read a value from instrument. It showed water activity of seeds, then changed water activity value into moisture in percentage unit by seed viability.

Seed germination percentage

The germination percentage of sample (Khao Dawk Mali 105 rice seed) was determined by using top of paper method with 4 replications (in 1 replication has 50 seeds) in controlled temperature germinator at 25^{o}C. The number of germinated seeds were counted at 5 days for first count and at 14 days for final count after plant the sample (ISTA, 2019). Germination percentage was calculated by below formula:

$$\text{seed germination}\ (\%) = \left[\frac{\text{number of normal seedlings}}{\text{number of cultivated seeds}}\right] \times 100$$

Germination index

The germination index of sample (Khao Dawk Mali 105 rice seed) was determined according to the method of seed germination examination. Counting the number of normal germinated seeds was performed on day 5 (as the first count) and day 14 (as the final count) (ISTA, 2019). Germination index was calculated by below formula:

$$\text{germination index} = \Sigma \left[\frac{\text{number of normal seedlings in each days}}{\text{number of days after cultivation}}\right]$$

Results

The suitable drying methods of primed rice seeds were examined for 5 month storage. The different drying methods provided the different results at the level of statistical confidence of 99%, compared to control at month 0, 1, 3 and 5. From month 0 to month 5, the highest moisture contents were found by the method of using a hot air oven at 25 ℃ for 48 h, followed by at 40 ℃ for 12 h. The two least moisture contents were found in rice seeds by the method of using a hot air oven at 30 ℃ for 36 h and at 35 ℃ for 24 h, respectively (Table 1).

For the effects of the storage environment, the results indicated the difference with the level of statistical confidence at 99% by paired comparison at 0 month and 5 months, and the difference with the level of statistical confidence at 95% by paired comparison at 1 month and 3 months. The storage at month 0 in the controlled environment showed the highest moisture content in the sample of rice seeds at 11.45%, and statistically different when compared to the storage in uncontrolled environments. The least moisture content was reported at 10.52% when storing rice seeds for 1 month in the uncontrolled environment, and statistically different when compared to the storage in uncontrolled environments. Although the results by months were statistically different, the results between environment conditions were statistically different. The higher moisture content in the rice seeds was found from the storage condition of the uncontrolled environment than of the controlled environment (Table 1).

The relationships between the drying method and the storage condition of rice seeds showed the difference with the level of statistical confidence at 99% at month 0, 3 and 5, except at month 1. From month 1 to 5, the drying method using a hot air oven at 25 ℃ for 48 h in the controlled environment shows the result of the highest moisture content when compared to other methods. The next highest moisture content was found in the drying method using a hot air oven at 25 ℃ for 48 h in the uncontrolled environment. The highest moisture content at month 0 overall was reported at 13.25% from the drying method using a hot air oven at 25 ℃ for 48 h in uncontrolled environment. The highest moisture contents at month 1 were reported at

12.39% from the drying method using a hot air oven at 25 ℃ for 48 h in controlled environment. A drying method by using a hot air oven at 30 ℃ for 36 h in the uncontrolled environment provided the least percentage of moisture content in rice seeds when compared to other methods in the same months at 9.75%. The results at month 3 and 5 from a drying method by using a hot air oven at 30 ℃ for 36 h in the controlled environments also provided the least moisture content when compared to other relationships at the same month at 10.36% and 9.98%, respectively. However, this result at month 3 was not statistically different when compared to the result at month 3 from a drying method using a hot air oven at 35 ℃ for 24 h in the controlled environment at 10.43% (Table 1).

Table 1. Seed moisture content of Khao Dawk Mali 105 dried rice seed with drying methods before and after stored in different conditions for 5 months

Factors		Seed Moisture Content[1/] (%)			
		Month 0	**Month 1**	**Month 3**	**Month 5**
Drying method					
Control		11.11 b	10.37 c	11.06 b	10.58 c
25 ℃ / 48 hrs.		13.23 a	12.29 a	12.83 a	12.49 a
30 ℃ / 36 hrs.		10.36 c	9.85 d	10.53 c	10.29 d
35 ℃ / 24 hrs.		10.51 c	9.80 d	10.66 c	10.50 c
40 ℃ / 12 hrs.		11.22 b	10.49 b	11.21 b	10.91 b
Storage condition					
Controlled		11.45 a	10.60 a	11.18 b	10.85 b
Uncontrolled		11.12 b	10.52 b	11.34 a	11.06 a
Drying method x Storage condition					
Control	Controlled	11.51 b	10.37	10.83 e	10.54 d
	Uncontrolled	10.72 cd	10.37	11. 29 c	10.63 d
25 ℃ / 48 hrs.	Controlled	13.21 a	12.39	12.99 a	12.66 a
	Uncontrolled	13.25 a	12.20	12.67 b	12.32 b
30 ℃ / 36 hrs.	Controlled	10.27 e	9.95	10.36 g	9.98 f
	Uncontrolled	10.46 cde	9.75	10.71 ef	10.60 d
35 ℃ / 24 hrs.	Controlled	10.63 cde	9.79	10.43 fg	10.31 e
	Uncontrolled	10.40 de	9.81	10.89 de	10.70 d
40 ℃ / 12 hrs.	Controlled	11.63 b	10.49	11.28 c	10.75 d
	Uncontrolled	10.80 c	10.50	11.15 cd	11.06 c
F-test					
Drying method		**	**	**	**
Storage condition		**	*	*	**
Drying method x storage condition		**	ns	**	**
C.V. (%)		2.21	1.08	1.76	1.31

ns: not significantly different, * and ** significantly different at 95% and 99% levels.

[1/]Different uppercase letters in same vertical are significantly different by method of Duncan's New Multiple Range Test (DMRT).

For the water activity, the moisture in rice seeds was measured by RR moisture analyzer which can calculate the moisture content from the water activity result. For the effects of drying methods, the results of moisture content in stored rice seeds from 0 to 5 months indicated the difference with the level of statistical confidence at 99%. From 0 to 5 months, the highest moisture contents were found by a method of using a hot air oven at 25 ℃ for 48 h, followed by a control. The least moisture contents were found in rice seeds by a method of using a hot air oven at 30 ℃ for 36 h and at 35 ℃ for 24 h, respectively (Table 2).

For the effects of storage conditions, the rice seeds which were dried to reduce moisture contents by different methods and stored for 5 months did not provide statistical difference between the results of month 0 to 3. However, the statistically different result at the level of confidence at 99% was found at month 5. The highest moisture content shows in the uncontrolled environment at 12.97% which is statistically different by paired comparison to the result of the same month in the controlled environment at 12.73% (Table 2).

The relationships between the drying method and the storage condition of rice seeds was not different statistically at month 0 and 3. However, the difference with the level of statistical confidence at 99% could be observed at month 5. The drying method using a hot air oven at 25 ℃ for 48 h in the controlled environment had the result of the highest moisture content when compared to other methods, but it was not statistically different to the result of the drying method using a hot air oven at 25 ℃ for 48 h in the uncontrolled environment at 13.75%. The second highest moisture content was found in the drying method using a hot air oven at 40 ℃ for 12 h in the uncontrolled environment at 13.04%, but it was not statistically different to the result of the control method in the controlled and uncontrolled environment, the drying method using a hot air oven at 30 ℃ for 36 h in the uncontrolled environment, at 35 ℃ for 24 h in the uncontrolled environment, and at 40 ℃ for 12 h in the controlled environment at 12.84%, 12.79%, 12.66%, 12.64% and 12.67%, respectively. The drying method by using a hot air oven at 30 ℃ for 36 h in the controlled environment provided the least percentage of moisture content in rice seeds at 11.83%, which was statistically different from the results of other methods in the same month (Table 2).

Table 2. Seed moisture content transformed seed water activity of Khao Dawk Mali 105 dried rice seed with drying methods before and after stored in different conditions for 5 months

Factors		Seed Moisture Content[1/] (%)			
		Month 0	**Month 1**	**Month 3**	**Month 5**
Drying method					
Control		12.16 b	12.76 b	12.92 b	12.81 b
25 ℃ / 48 hrs.		13.52 a	13.81 a	13.87 a	13.91 a
30 ℃ / 36 hrs.		11.42 c	11.57 d	12.23 d	12.25 c
35 ℃ / 24 hrs.		11.63 c	11.62 d	12.38 cd	12.43 c
40 ℃ / 12 hrs.		12.43 b	12.25 c	12.80 bc	12.86 b
Storage condition					
Controlled		12.22	12.39	12.74	12.73 b
Uncontrolled		12.24	12.41	12.94	12.97 a
Drying method x Storage condition					
Control	Controlled	12.08	12.78	12.78	12.84 b
	Uncontrolled	12.23	12.75	13.07	12.79 b
25 ℃ / 48 hrs.	Controlled	13.52	13.87	14.15	14.08 a
	Uncontrolled	13.53	13.76	13.59	13.75 a
30 ℃ / 36 hrs.	Controlled	11.40	11.56	12.03	11.83 d
	Uncontrolled	11.43	11.58	12.44	12.66 b
35 ℃ / 24 hrs.	Controlled	11.65	11.49	12.10	12.22 c
	Uncontrolled	11.61	11.75	12.65	12.64 b
40 ℃ / 12 hrs.	Controlled	12.46	12.28	12.64	12.67 b
	Uncontrolled	12.40	12.22	12.96	13.04 b
F-test					
Drying method		**	**	**	**
Storage condition		ns	ns	ns	**
Drying method x storage condition		ns	ns	ns	**
C.V. (%)		2.54	3.22	3.51	1.97

ns: not significantly different, ** significantly different at 99% level.
[1/]Different uppercase letters in same vertical are significantly different by method of Duncan's New Multiple Range Test (DMRT).

The germination percentage of primed rice seeds were examined after moisture reduction by drying methods and storage for 5 months. For the effects of drying methods, the result of germination percentage at each month was statistically different with the level of confidence at 99%, except at month 1. At month 0, the result of the drying method using a hot air oven at 40 ℃ for 12 h yielded the highest germination percentage, compared to other methods, but it was not statistically different from the control and the drying method using a hot air oven at 35 ℃ for 24 h. Followed by the drying method using a hot air oven at 25 ℃ for 48 h, the germination percentage yielded at 81.25%, but it was not statistically different from the result of the drying method using a hot air oven at 30 ℃ for 36 h which was 79.75%. At month 5, the result of the drying method using a hot air oven at 35 ℃ for 24 h yielded germination at 92.25%, but it was not statistically different from the result of the drying method using a hot air oven at 40 ℃ for 12 h as well as at 30 ℃ for 36 h. The next one is the control which yielded 74.75% of germination. The drying method using a hot air oven at 25 ℃ for 48 h yielded the least germination percentage when compared to other methods (Table 3).

For the effects of storage conditions, the rice seeds which were dried to reduce moisture contents by different drying methods and stored for 5 months provided the results at month 3 and 5 with statistical difference at the confidence level of 99%, at month 0 with the confidence level of 95% and at month 1 without statistical difference. At month 0, the uncontrolled environment storage provided the germination of rice seeds at 87.10% which is statistically different from the controlled environment storage which provided the germination of rice seeds at 84.00%. From month 3 to 5, the statistical difference was observed between uncontrolled and controlled environments. Overall, the highest germination was reported from the controlled environment at 92.50% in month 5 of storage (Table 3).

The relationship between the drying method and the storage condition of rice seeds shows that the result was not statistically different from month 0 to 3. However, it shows the difference with the level of statistical confidence at 99% at month 5. The result of the drying method using a hot air oven at 40 ℃ for 12 h in the controlled environment provided the highest germination, when compared to other methods. However, it was not statistically different to the results of the control method in the controlled environment, the drying method using a hot air oven at 25 ℃ for 48 h in the uncontrolled environment, at 30 ℃ for 36 h in both environments, at 35 ℃ for 24 h in the environment, and at 40 ℃ for 12 h in the uncontrolled environment. In overall, the drying method using a hot air oven at 25 ℃ for 48 h in the uncontrolled environment provided the least germination percentage (Table 3).

Table 3. Seed germination percentage of Khao Dawk Mali 105 dried rice seed with drying methods before and after stored in different conditions for 5 months

Factors		**Seed Germination[1/] (%)**			
		Month 0	**Month 1**	**Month 3**	**Month 5**
Drying method					
Control		87.25 a	87.75	76.50 c	74.75 b
25 ℃ / 48 hrs.		81.25 b	88.75	82.25 bc	47.75 c
30 ℃ / 36 hrs.		79.75 b	88.00	85.50 ab	89.25 a
35 ℃ / 24 hrs.		88.25 a	85.25	90.25 a	92.25 a
40 ℃ / 12 hrs.		91.25 a	84.75	87.50 ab	91.25 a
Storage condition					
Controlled		84.00 b	86.50	88.90 a	92.50 a
Uncontrolled		87.10 a	87.30	79.90 b	65.60 b
Drying method x Storage condition					
Control	Controlled	86.50	85.50	86.00	91.00 a
	Uncontrolled	88.00	90.00	67.00	58.50 b
25 ℃ / 48 hrs.	Controlled	80.50	86.00	87.50	91.00 a
	Uncontrolled	82.00	91.50	77.00	40.50 c
30 ℃ / 36 hrs.	Controlled	75.50	89.00	89.00	91.50 a
	Uncontrolled	84.00	87.00	82.00	87.00 a
35 ℃ / 24 hrs.	Controlled	88.50	84.50	92.50	93.50 a
	Uncontrolled	88.00	86.00	88.00	91.00 a
40 ℃ / 12 hrs.	Controlled	89.00	87.50	89.50	95.50 a
	Uncontrolled	93.50	82.00	85.50	87.00 a
F-test					
Drying method		**	ns	**	**
Storage condition		*	ns	**	**
Drying method x storage condition		ns	ns	ns	**
C.V. (%)		5.3	4.8	7.18	7.01

ns: not significantly different, * and ** significantly different at 95% and 99% levels.
[1/]Different uppercase letters in same vertical are significantly different by method of Duncan's New Multiple Range Test (DMRT).

For the effects of the drying method on the germination index after 5 month storage, it was not statistically different at month 0 but the results were statistically different with the level of confidence at 99% at month 1 to 5. At month 1, the drying method using a hot air oven at 40 ℃ for 12 h had the highest germination index, compared to other methods. The second highest index was reported from the drying method using a hot air oven at 35 ℃ for 24 h at 10.39, but this result was not statistically different when compared to the drying method using a hot air oven at 30 ℃ for 36 h and at 25 ℃ for 48 h. The least germination index was reported from the control experiment when compared the results in the same month. At month 3, the drying method using a hot air oven at 35 ℃ for 24 h had the highest germination index, but this result was not statistically different when compared to the drying method using a hot air oven at 40 ℃ for 12 h and at 30 ℃ for 36 h. The second highest index was reported from the drying method using a hot air oven at 25 ℃ for 48 h at 8.92. The least germination index was reported from the control experiment when compared the results in the same month. At month 5, the drying method using a hot air oven at 35 ℃ for 24 h had the highest germination index, but this result was not statistically different when compared to the drying method using a hot air oven at 40 ℃ for 12 h and at 30 ℃ for 36 h. The second highest index was reported from the control experiment at 10.80. The least germination index was reported from the drying method using a hot air oven at 40 ℃ for 12 h when compared to the results from the same month (Table 4).

For the effects of storage conditions, the rice seeds which were dried to reduce moisture contents by different drying methods and stored for 5 months provided the result at month 3 and 5 with statistical difference at the confidence level of 99%. However, the result at month 0 and 1 did not have statistical difference. The controlled environment provided a higher germination index than the results from the uncontrolled environment (Table 4).

The relationship between the drying method and the storage condition of rice seeds shows the results with statistical difference in every month, except the result of month 3. At month 1, the result of the drying method using a hot air oven at 25 ℃ for 48 h in the controlled environment provided the highest germination index, but this result was not statistically different when compared to the control experiment in the controlled environment and the drying method using a hot air oven at 30 ℃ for 36 h in the uncontrolled environment. At month 1, the result of the drying method using a hot air oven at 40 ℃ for 12 h provided the highest germination index when compared to the results from other methods at the same month, but this result was not statistically different when compared to the same drying method in the uncontrolled environment. At month 5, the result of the drying method using a hot air oven at 40 ℃ for 12 h in the controlled environment provided the highest germination index, but this result was not statistically different when compared to all drying methods in the controlled environment as well as the drying method using a hot air oven at 35 ℃ for 24 h in the uncontrolled environment. Furthermore, the drying method using a hot air oven at 25 ℃ for 48 h in the uncontrolled environment provided the least germination, when compared to the results from other methods at the same month (Table 4).

Table 4. Germination index of Khao Dawk Mali 105 dried rice seed with drying methods before and after stored in different conditions for 5 months

Factors		Germination index[1/]			
		Month 0	**Month 1**	**Month 3**	**Month 5**
Drying method					
Control		11.60	6.26 c	6.75 c	10.80 b
25 ℃ / 48 hrs.		13.45	9.39 b	8.92 b	9.26 c
30 ℃ / 36 hrs.		10.00	10.20 b	11.53 a	17.56 a
35 ℃ / 24 hrs.		9.61	10.39 b	13.03 a	18.22 a
40 ℃ / 12 hrs.		10.11	13.35 a	12.61 a	17.80 a
Storage condition					
Controlled		11.15	9.98	12.12 a	18.25 a
Uncontrolled		10.76	9.86	9.02 b	11.20 b
Drying method x Storage condition					
Control	Controlled	14.47 ab	6.11 g	8.45	17.43 ab
	Uncontrolled	8.72 d	6.42 fg	5.04	4.18 c
25 ℃ / 48 hrs.	Controlled	16.10 a	8.00 ef	11.77	18.20 ab
	Uncontrolled	10.81 bcd	10.78 cd	6.08	0.32 d
30 ℃ / 36 hrs.	Controlled	6.68 d	10.53 cd	12.46	18.17 ab
	Uncontrolled	13.33 abc	9.87 cde	10.61	16.95 b
35 ℃ / 24 hrs.	Controlled	8.25 d	11.69 bc	13.74	18.63 a
	Uncontrolled	10.97 bcd	9.10 de	12.33	17.81 ab
40 ℃ / 12 hrs.	Controlled	10.28 bcd	13.58 a	14.17	18.84 a
	Uncontrolled	9.95 cd	13.12 ab	11.05	16.75 b
F-test					
Drying method		ns	**	**	**
Storage condition		ns	ns	**	**
Drying method x storage condition		**	**	ns	**
C.V. (%)		25.29	12.46	19.28	0.98

ns: not significantly different, ** significantly different at 99% level.
[1/]Different uppercase letters in same vertical are significantly different by method of Duncan's New Multiple Range Test (DMRT).

Discussion

Seed priming is a pre-treatment which enables seeds to have high germination rate, physiological strength, environment tolerance and yield per plot (Santipracha, 1987). It is relatively easy and low cost for farmers to process (Siri, 2015). However, this treatment to stimulate germination often encounters problems about moisture content. It is challenging to reduce the moisture content of the seeds to be low as the previous state before treatment. If the moisture content cannot be reduced, the shelf-life of the seeds is also reduced. As a result, the primed seeds can be rotted shortly after storage which leads to the problems about seed quality and agricultural yield. In this study, a suitable drying method for primed Khao Dawk Mali 105 rice seeds by using a hot air oven at 30 ℃ for 36 h shows the best performance in reducing moisture content with the highest germination and germination index results. It is reported that using the slow process for moisture reduction in primed seeds provided higher seed quality, germination value and germination rate than using the fast process (Schwember and Bradford, 2005). According to the experimental results, this method can reduce moisture content in seeds efficiently into a similar level of the seeds prior to a priming treatment. Therefore, the seeds have a good germination value and index after drying and storing for 5 months. The reason behind this is that the higher moisture, the higher respiratory of the seeds which accelerates the decay process (Samphunphuang *et al.*, 2016). There are many studies that provide supportive results of Hlyka and Robinson (1954) show that seeds with high moisture content usually lose germination rate quickly, while seeds with low moisture content still have good germination rate after storage. Schwember and Bradford (2005) found that when primed cabbage seeds were dried using a slow process at 20 ℃ for 24 h, their quality is higher than dried seeds obtained from a fast drying process. Parawisut *et al.* (2005) investigated the suitable temperatures of a drying oven for reducing moisture in seeds. They compared the constant temperatures to increasing temperatures by time at 40 ℃, 45 ℃ and 50 ℃. Their results show that the method that could reduce moisture content from 20% to 12% was effective, but the germination and shelf-life were not significantly different between oven-dried seeds and sun-dried seeds.

According to the study, primed Khao Dawk Mali 105 rice seeds in different storage conditions show that the controlled environment provided the better seed quality due to a hygroscopic property of seeds. This property allows seeds to absorb moisture from the atmosphere and surrounding environment until equilibrium and the moisture content in seeds becomes constant. If the surrounding moisture is not constant, it will affect the quality of seeds (Duangpatra, 1986). Chapman and Robertson (1987) reported that the effect of high moisture in the storage room could decrease the shelf-life of seeds quickly. After the moisture content is reduced into the desired level, it is recommended that the seeds should be kept in the closed containers to prevent moisture absorption and in the controlled environment to prolong seed quality (James, 1967). This experiment shows that drying primed Khao Dawk Mali 105 rice seeds at 30 ℃ for 36 h and storing in the controlled environment was the most effective method to provide high germination percentage and index. Correspondingly, Coradi *et al*. (2020) studied the storage conditions of soybeans and found that keeping laminated-coated seeds in the storage bag under the controlled environment could extend shelf-life of soybeans to a longer duration than under the uncontrolled environment. Kulnoi and Boondauylan (2020) also reported similar experimental results on sunflower seeds that keeping seeds in the aluminum bag under controlled temperature and relative humidity provided the least moisture content percentage and highest germination result.

Acknowledgements

We would like to thank The Faculty of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Thailand for the financial support for this research.

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(Received: 13 September 2021, accepted: 10 February 2022)