International Conference onCapacity Building for Research and Innovation in Disaster Resilience2019

Effect of Global Warming on Dry Mass Loss of Paddy Stored in Gunny Bags

M.G.G Awanthi*[a], S.B. Navaratne[b], B.M.S Jinendra[a], C.M. Navaratne1[a]

[a]*Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kambutrupitiya (81100), Sri Lanka*
[b] *Department of Food Science and Technology, Faculty of Applied Science, University of Jayewardhenepura, Nugegoda (10250), Sri Lanka*

Abstract

The objective of this study was to assess the dry mass loss (DML) of paddy stored in gunny bags at different temperatures in simulation with global warming and to suggest adaptation techniques for minimizing DML. Five kilograms of paddy were packed in gunny bags and stored in temperature-controlled chambers for 6 months. Results revealed that the DML of raw paddy was increased with the elevated storage temperature and itcan be expressed in a multiple regression equation. It could be recommended that varietal selection and parboiling are best practices when storing paddy to cope with global warming.

*Keywords:*Dry mass loss; Global Warming; Respiration; Storing Paddy; Temperature.

1. Introduction

Global warming has become a major concern in the world today. Increasing temperature is the instant and most obvious effect of global warming. A scenario of comparatively high greenhouse gas emissions called RCP8.5 predicted that global mean surface temperature will increase from 2.6 to 4.8°C by the end of the 21st century [1]. Similarly, analysis of data on temperature from 1961 to 1990, has revealed that mean temperature in Sri Lanka may rise by approximately 0.9 - 4°C by the year 2100 [2]. Consequently, many problems will have to be faced by the global community such as rising sea levels, altering local climaticconditions, affecting forests, crop yields and water supplies. However, global warming will continue to exert its influence not only on crop production, but also on the increasingly valuable harvested commodity and post-harvest activities [3].

Recorded average day time maximum temperature of countries in the tropical belt area is around 32°C and may exceed to 35ºC[4]. Rice is the major crop which can be influenced by elevated temperature in this area. Therefore, production of rice will be a challenging issue in rice-growing areas. Quality degradation and reduction of paddy yieldwithin the period fromplanting to harvesting are the major issues that have occurred due to high ambient temperature[5].Besides the yield, rising temperature can be a hugeeconomic threat even on post-harvest operations including harvesting, drying, processing, pest and disease management, packaging and storage [3].Among the different post-harvest activities, rising temperature can causedetrimental effects during storage because storing paddy appropriately for a long time is of urgent need.For instance, Sri Lankan farmers tend to stock about 50% of harvested paddy for their consumption, seeds and future sale for a period of 6-12 months [3].

One of the prominent issues on harvested commodities in many developing countries is deterioration of food sources due to hot and humid climates[6]. It was revealed that storage temperature is closely related to changes in quality and mass loss of paddy, the higher the temperature, the faster the deterioration, the faster the decline of vitality and shorter safe storage period [7]. Global warming and increment of corresponding temperature affectsrespiration of harvested foods. Since structural carbohydrates of foods combust in the respiration process, dry mass loss (DML) can occur with quality degradation of harvested foods. Therefore, respiration is the main process to be controlled after crops have been harvested. It was found that respiration rate increases with temperature up to a certain point and then begins to decline. For an example, as an indicator of DML, soluble sugar content of corn stored at 45°C over a six month period decreased until its moisture content was 20.4% [8]. In perishables rate of deterioration increases by 2 or 3 fold for each increase of 10°C above optimum [9]. Similarly, as durables, corn stored at 10 to 30°C with 14 to 22% moisture, showed around doubled respiration rate with each 10°C increase in temperature. [10]. However, post-harvest physiologists and food scientists have restricted alternatives that interfere with the respiratory process, since majority of them depend on specific characteristics of harvested commodities [11].

2. The object of the study

Although there were numerous evidence to prove the negative effects of increasing temperature on paddy yield, a little is recorded about its effects on stored paddy. Moreover, as storage temperatures of paddy depend on the influence of external factors such as radiation, conduction and convection depending upon the climactic condition [12], understanding the effect of global warming on quality deterioration of stored paddy is vitally important. Therefore, the main objectives of this study wereto assess the DML of paddy stored in gunny bags at different temperatures in line with global warming and to identify adaptation techniques for minimizing DML of paddy at storage.

3. Methods

3.1 Fabrication of temperature controlling device

Four wooden chambers were fabricated as storage structures under controlled conditions of temperature. Selected temperature levels for the study were 26, 30, 34 and 38°C. The most appropriate distances to keep paddy bags in chambers were observed by changing the distances of upper most shelves and making holes at thebottom.These chambers were equipped with bulbs (100W) to supply heat energy and an electric sensor board was developed to maintain the stipulated temperature consistently. The Arduino Micro controller system was equipped using DHT 11 temperature and relative humidity sensors to record temperature and relative humidity data inside and outside the chambers during the experiment.

3.2 Sample preparation

The study was conducted at Faculty of Agriculture, University of Ruhuna, Sri Lanka. AT-362 (an improved paddy variety) and Kuruluthuda (a traditional paddy variety) were selected for the experiment considering their abundance in the designated experimental area. Two hundred and forty kilograms of fresh paddy harvested in the Maha season (2016/2017) were collected, cleaned and dried to get 14% of the moisture content as this moisture content assured safe storage for a long period. Half of the paddy were parboiled using the IPHT parboiling process [13]. Then the paddy was disinfected using chloroform (CHCl3) vapour for 12 h in a gastight chamber to avoid the attack of possible pests and microbes during the storage period [14].

3.3 Storing paddy

About 50 ml of Phirimiphos methyl (500g/L EC) was dissolved in 4.5L of water and the prepared solution wassprayed on packing materials [13]. Five Kilograms of paddy were packed in prepared gunny bags to build a sample unit. The length and width of a bag was 0.45m and 0.3m respectively. Gunny bags were closed with 5 mm wide PVC cable connectors. Packed paddy were stored under 4 different temperatures, namely 26, 30, 34 and 38°C for 6 months.

3.4 Experimental Design

The study was conducted according to split-split plot design while replicating all treatment thrice. The variety is the main plot factor with 2 levels (AT-362, Kuruluthuda), processing technique is the sub plot factor with 2 levels (raw, parboiled) and temperature is the sub-sub plot factor with 4 levels (26, 30, 34 and 38°C).

3.5 Data collection

Samples were drawn at 4 week intervals for a period of 6 months and subjected to determine moisture content and 1000 grain weight, as these two parameters are important to calculate dry mass loss of grains against the period of storage and stored temperature. Dry mass loss was calculated using equation 3.1 [7].

$$L(\%) = \frac{[G_1 (1- W_1) - G_2 (1- W_2)]}{G_1 (1- W_1)} \times 100\% \text{----Eq: 3. 1}$$

Where: L = mass loss rate (dry- basis)

G_1 = Initial 1000 grain weight (g);

G_2 = 1000 gram weight after storage (g) ;

W_1 = Initial grain moisture content of the sample (%);

W_2 = The grain moisture content In the sack after storage (%).

2.3 Data analysis

All the analyses were performed in triplicates and presented as mean ± standard deviation. Statistical significance of the data obtained was analyzed by analysis of variance (ANOVA) followed by LSD test using Statistical Analysis System (SAS). The level of significance was considered at $P < 0.05$. Furthermore, multiple regression analysis was undertaken to develop equations.

4. Results and Discussion

4.1Changes in DML of raw paddy

Results revealed that DML depends on the combined effects of levels of all 3 factors rather than that of their individual effects, because 3 factor interaction was significant in the third ($F_{3,24}$=3.97, P<0.05), fourth ($F_{3,24}$=3.2, P<0.05) fifth ($F_{3,24}$=5.44, P<0.05) and sixth month ($F_{3,24}$=3.03, P<0.05). As shown in Figure 4.1, the rate of DML steadily increaseswith time for both paddy varieties. A positive correlation between storage time and DML of raw paddy (r=0.76; P<0.05) was found for a period of six months. The highest DML was shown by raw AT-362 variety (2.27 ± 0.156%) when stored at 38ºC after 6 months. The lowest DML occurred at 26ºC aftera month inboth paddy varieties.

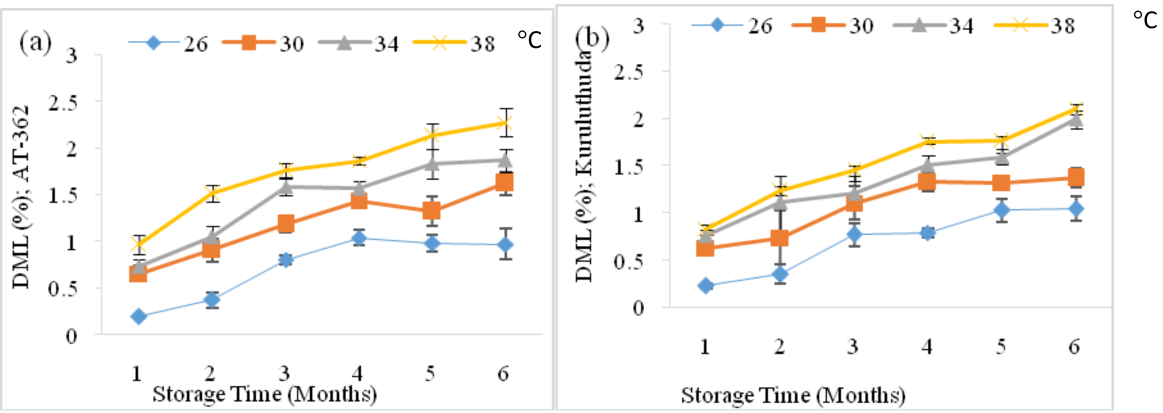

Figure 4. 1 Changes in DML rate of raw paddy (a) AT-362 and (b) Kuruluthuda stored at 4 temperature levels for 6 months

The DML was significantly higher (P< 0.05) at 38ºC compared to DML at 26ºC during the six month period of storage in both varieties. Similarly, Navaratne *et al.* [15] studied the effects of temperature on DML of paddy, green gram corn and cowpea. They reported that DML of grains stored at higher temperature (>35°C) for 4 months was higher due to the rapid rate of respiration and it was vice versa when grains were stored at low temperatures, preferably less than 30°C. Furthermore, when storage temperature increased from 26ºC to 38ºC (by 12ºC), the rate of DML was more than double for both types of paddy varieties until the 3rd month of the storage period. Previous studies support this phenomenon as corn stored at 10° and 30°C with 14 to 22% moisture contents, the rate of respiration was doubled withthe increment of temperature by 10ºC [10].

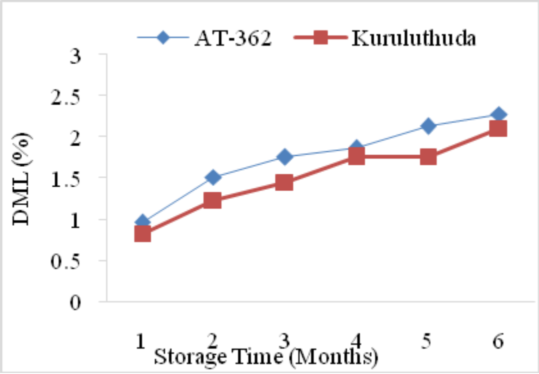

Figure 4. 2Changes in DML of raw paddy stored at 38ºC for 6 months

This research study indicated that AT-362 has a higher DML than Kuruluthuda in raw during storage as indicated in Figure 4.2. This is most probably due to the thickness variation of paddy husk in two paddy varieties. Paddy husk is an excellent insulating material, which can prevent heat flow by conserving energy flow through the gain to loss [16]. Sreenarayanan *et al.*, [17]found that paddy husk can be used as a heat resistant material by using transient heat flow method. Furthermore, thermal resistance value can be increased with the thickness of the insulating material [18]. This study estimated that thickness of husk in Kuruluthuda (0.2 mm) is higher than AT-362 (0.1 mm). Therefore, Kuruluthuda has a high thermal resistance and as a result it may show less dry mass loss compared to AT-362 stored at the same temperature.

4.2 Changes in DML of parboiled paddy

Dry mass loss of parboiled paddy ranged from 0.019±0.003 to 0.084±0.009 for AT-362 and 0.028±0.017 to 0.081±0.010 for Kuruluthuda. The results further revealed that DML of parboiled paddy of both varieties was remarkably lower than ($P<0.05$) that of raw paddy stored at 4 different temperature levels each month. The lowDML in parboiled paddy may be due to destroying and conversion ofenzymes present in the rice to an inactive form as a result of heat applied during steaming in the parboiling process [19]. Therefore, most biological processes, such as germination, respiration, and any other form of biological activities do not occur in parboiled rice. In this study, lowDML of parboiled paddy may be strengthened by the fact that their maximum allowable storage time would be more than 6 months. However, no significant difference was found between raw and parboiled paddy on both varieties stored at 26ºC during the first 2-3 months. This may be due to low DML at low temperatures in raw paddy varieties during the early period of storage [7], which was almost close to a lowrate of DML in parboiled rice

4.3 Determination of maximum allowable storage time in terms of DML

Teter [20]suggested that the deterioration of paddy in terms of DML should not exceed 0.8% at the end of the storage period. Furthermore, according to the grading system developed by Sukabdi [21], when the rice lost approximately 0.75% dry matter; it can be graded in to U.S No 2. Therefore, maximum allowable storage time was determined by estimating the storage time thatrequired 0.8% of dry matter to be lost during the storage period by this study.

The maximum allowable time for raw paddy stored in gunny bags at different temperature levels arepresented in Table 4.1. The longest maximum allowable storage time (120 days) was recorded by raw Kuruluthuda stored at 26ºC. Thus, when the storage temperature is increasing, maximum allowable storage time required to lose 0.8% dry matter in raw paddy reciprocally decreases due to increasing respiration rate. Similar findings have been reported by Mutters and Thompson [21],who projected that paddy /rice stored at 20, 25, and 30°C temperatures with 16% initial moisture content would lose 0.5% of its dry matter weight during 13, 5, 1.7 months respectively. However, similar maximum allowable storage time (40 days) were recorded at 29.5ºC and 35ºC to lose 0.5% dry matter of paddy with 15% of initial moisture content [22]. DML of parboiled paddy were less than 0.8% DML respectively in this study. Therefore, maximum allowable storage time for parboiled paddy would be more than 6 months irrespective of temperature increment

Table 1. Maximum allowable time of raw paddy stored in gunny bags at different temperature levels

Temperature (ºC)	Maximum allowable storage time	
	AT-362	Kuruluthuda
26	115	120
30	69	63
34	60	40
38	42	38

4.3 Development of equation to determine the dry mass loss

Equations were developed using multiple linear regression to quantify the DML of two paddy varieties in raw form because there were no correlations in the DML of parboiled paddy. Results revealed that there is a strong positive co-relationship ($p<0.05$, R-Sq = 88.0%) between dry mass loss of raw paddy against 3 variables such as stored temperature, storage time and variety as shown in equation 2. Equations 3 and 4 impart the quantification of DML loss of AT-362 variety ($p<0.05$;R-Sq = 87.2%) and Kuruluthuda variety ($p<0.05$; R-Sq = 89.8%) respectively.

DML = - 2.02+ 0.0834 T + 0.203 S- 0.107 V ---------------Eq:02

DML = -2.37 + 0.0906 T + 0.206 S ---------------------------Eq:03

DML = - 1.99 + 0.0761 T + 0.200 S --------------------------Eq:04

T = Storage temperature (°C), S = Period of storage (month), V=Paddy Variety (0 for improved/At 362 variety, 1 for traditional/Kuruluthuda variety)

5. Conclusion

The studied high temperature profiles that simulate the upcoming global worming scenarios have adversely affected the quality of stored paddy by means of dry mass losses. Dry mass loss was nearly doubled when storage temperatures is increased from 26 to 38°C in raw paddy. Therefore, maximum allowable storage time of paddy decreased drastically with the increment of temperature. The changes in DML in stored raw paddy can be measured using a developed equation as a function of temperature, variety and time. However, DML of parboiled paddy appears to be significantly lower than raw paddy in both varieties at 30°C, 34°C and 38°C. Since raw Kuruluthuda paddy variety showed lower DML than AT-362, selecting appropriate paddy varieties or genetically transforming the properties is the subsequent option available for mitigating the impacts. However, as traditional varieties giving the low productivity, the practically viable option would be parboiling as an adaptation technique for global warming.

References

1. IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II&III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team. IPCC, Geneva Switzerland, 151.
2. Eriyagama, N., Smakhtin, V., Chandrapala, L. & Fernando, K. (2010). Impacts of climate change on water resources&agriculture in Sri Lanka: a review&preliminary vulnerability mapping. Colombo, Sri Lanka: International Water Management Institute. (IWMI Research Report 135), 51.
3. Stathers, T., Lamboll, R.&Mvumi, B.M. (2013). Post-harvest Agriculture in a changing climate. International Jornal of Rural Development 47(1), 12-14.
4. OneStat.com United Kingdom Apache Solutions Ltd. Tropical Climate, Encyclopedia of the Atmospheric Environment, http://www.ecoca.ro/meteo/tutorial/Climate/Older/ Tropical Climate.html.
5. Peng, S., Huang, J., Sheehy, J.E., Laza, R.C., Visperas, R.M., Zhong, X., Centeno, G.S., Khush, G.S.&Cassman, K.G. (2004). Rice yields decline with higher night temperature from global warming. Proceedings of the National academy of Sciences of the United States of America, 101(27), 9971-9975.

6. Faure, J. (1987). 'The Influence Of Storage On Quality Criteria Of Tropical Grains' Proceedings of the 4th International Working Conference on Stored-Product Protection, Montpellter, France, 355-384.

7. Gao, Y., Yang, J., Lan, S., Zhan, H., Wang, S.&Chen, L.I. (1999). Effects of temperature on rice quality&mass loss. Proceedings of the 7th International working conference on stored-product protection, 2, pp.1413-1421.

8. Rehman, Z.U., Habib, F.&Zafar, S.I. (2002). Nutritional changes in maize (Zea mays) during storage at three temperatures. Food Chemistry, 77(2), 197–201.

9. Kader, A.A. (2002). Postharvest technology of horticultural crops, University of California Agriculture&Natural Resources, 3311.

10. Huang, H., Danao, M.G.C., Rausch, K.D.& Singh, V.(2013). Diffusion&production of carbon dioxide in bulk corn at various temperatures&moisture contents. Journal of stored products research, 55 (4), 21-26.

11. Moretti, C. L., Mattos, L. M., Calbo, A. G.,& Sargent, S. A. (2010). Climate changes&potential impacts on postharvest quality of fruit&vegetable crops: a review. Food Research International, 43(7), 1824-1832.

12. Chidan, D.V.& Shanmugasundaram, S. (2016). A study on storage temperature of paddy in metal silos, International Journal of Agricultural Science& Research, 6(2), 2321-0087.

13. IPHT (Institute of Post harvest Technology), Grain storage manual, Sri lanka.

14. Prasantha, B.R., Hafeel, R.F., Wimalasiri, K.M.S.& Pathirana, U.P.D. (2014). End-use quality characteristics of hermetically stored paddy. Journal of stored products research, 59, 158-166.

15. Navaratne, S.B.& Anjalo, M.D.S (2013). Assessment of dry mass loss of stored cereals due to increment of stored temperature in line with global warming. International Journal of Science&Research (IJSR), 2 (12), 24-27, ISSN: 2319-7064.

16. Jamil, N.& Bejo, S.K. (2014). Husk detection using thermal imaging technology. Agriculture&Agricultural Science Procedia, 2, 128-135.

17. Sreenarayanan, V.V.& Chattopadya, P.K. (1986). Thermal conductivity&diffusivity of rice bran. Journal Agriculture Engineering Research, 34, 115-121.

18. Shawyer, M.& Pizzali, A.F.M. (2003). The use of ice on small fishing vessels (No. 436). Food&Agriculture Organization.

19. Xavier, I.J.& Raj, S.A. (1995). Enzyme changes in rough rice during parboiling. Journal of food biochemistry, 19(5), 381-389.

20. Teter, N.C. (1981). Grain Storage. SEARCA College, Laguna, Philippines. pp. 86.

21. Mutters, R. G.,& Thompson, J. F. (2009). Rice quality handbook. Postharvest Technology Center, Department of Plant Sciences-Mail Stop 2, One Shields Avenue, University of California. UCANR Publications. 3514.

22. Sukabdi, A.(1979). Deterioration of Rough Rice as Measured by Carbon Dioxide Prediction. Master's Thesis, Department of grain science&industry, Kansas Stats University Manhattan , Kansas, 20-41.