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Study on the effects of storage conditions on pretreated and raw biomass

Tassanapark Nimitpaitoon *, Boonrod Sajjakulnukit

The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

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ABSTRACT

This study aims to investigate influential of the storage condition that affects biomass properties that are covering storages (covered and uncovered) of the torrefied and untorrefied pellets of wood and corncob pellets. And the properties of the pellet after storage for 6 months consist of higher heating value (HHV), moisture content, durability, and dry matter loss. The result shows that the torrefied (wood and corncob) pellets have higher HHV than untorrefied pellets around 15-30%. For the moisture content, the covered pellets have less moisture content than uncovered approximately 3% for both (wood and corncob pellets). Furthermore, the durability continuously decreases from start to 6 months until the durability of corncob black wood and corncob pellet decrease around 95.2% in the case uncovered while in the covered case of wood and corncob, the durability decline around 7.4% and 4.1% respectively. To sum up, the experiment demonstrates that piling a pellet under dry conditions (or covering the pellet to avoid moisture conditions) can upgrade the HHV and energy density of the pellet and the quality of torrefied pellet is greater than untorrefied pellet as well as the wood pellet quality is also better than corncob in term of a low increasing rate of moisture content and dry matter loss and higher of durability, HHV and energy density.

1. Introduction

Nowadays, the alternative fuel in the power plant especially biomass from agriculture is applied and studied in many countries around the world due to the more severe greenhouse effect that results from higher amounts of GHGs particularly CO_2 from fossil fuel combustion (Usón et al., 2013; Viana et al., 2010; Situmorang et al., 2020). And according to the Paris Agreement, the GHG emission target of Thailand in 2030 has been set to decrease the GHGs by around 20% from the projected from Business-As-Usual (BAU) (Rogelj et al., 2016). Typically, original raw material biomass has a high moisture content that must use some energy to change water to vapor. Improving the properties of biomass by torrefaction to decrease moisture content can increase the efficiency of biomass (Niu et al., 2019). Even refinery of biomass is a success but transportation and storage are a challenge for power plant users (Craven et al., 2015). Pelletization is a transformed process that compresses the biomass (for higher density) to be a pellet (Stelte et al., 2011). This is more convenient for transportation and usage including increasing the heating value of the biomass.

Pellet density can be affected by the time period in storage, but another factor has also influenced pellet density, that is the time period in the storage of raw material before use in pellet production. For example, the particle density test of canola straw pellets which are storage canola straw for 3, 7, and 10 months pelletization, and after that straw pellet was kept in storage for around 2-48 weeks. The result shows particle density has significantly been affected in the process due to the period of storage (Chico-Santamarta et al., 2012). Bulk density of straw pellet increases more than 10 times when compare with raw straw that can decrease volume in input process in combustion (Holm et al., 2006; Chico-Santamarta et al., 2012; Obernberger and Thek, 2004). Bulk density is influence to heat and moisture transfer especially dominated biomass by ventilation air on the stored pellets as shown in research, that the increasing rate of temperature at the top of silo was 2.4C◦/h (Larsson et al., 2012). The lack of raw materials is one problem for biomass pellets producing, that provoke many the pelletized

* Corresponding Author.
Email Address: tassanapark@hotmail.com (T. Nimitpaitoon)
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Corresponding author's ORCID profile:
https://orcid.org/0000-0002-7253-9932

factory to find new capable raw materials to produce pellet, such as corncob and bagasse.

The environmental factor, such as temperature, relative humidity, and particle in the air affect biomass properties that are the degradation, mechanical strength, moisture inside and composition of biomass, heating value, and durability. The quality change in pellets is not significant, but the pellets have disintegrated from storage (Chico-Santamarta et al., 2012). In addition to the ambient condition, the height of the pile, which was reported in Mendel et al. (2016) can affect the amount of water in pellets during storage as well as the shape of the pile also affects the moisture content. Moreover, the pretreating process and covering the storage are considered can affect the properties of the pellet. Therefore, this work aims to study the 3 factors that influence to variation of biomass mechanical properties such as covering, torrefaction process and type of biomass pellet. The covering of storage is tested by covering and uncovering the torrefied wood and corncob pellet pies. For torrefaction, this study is designed to compare the torrefied and unterrified wood and corncob pellets by storing them under the same condition (including covering the pellet with a plastic sheet). And comparing the change of mechanical properties of 2 types of torrefied pellets (wood and corncob) by storing the pellet in a controlled condition (including a cover by the plastic sheet).

2. Literature review

Pelletization and torrefaction are the processes of pretreated biomass for reducing transportation costs. Some research suggests that improving the pellet can increase the quality of the biomass in terms of physical properties such as increasing bulk density and improving storability. For more information readers are referred to Theerarattananoon et al. (2011). The torrefaction is a thermal pre-treatment process that can also improve some properties (in which the biomass is heated up to 200 to 300°C in the absence of oxygen or nitrogen atmosphere). This results in the product having a lower oxygen content, higher calorific value, low moisture content, and less hydrophilic compared to the untreated biomass For more information readers are referred to Stelte et al. (2012).

3. Method

3.1. Covering

The torrefied wood and corncob pellet are stored by piling them as shown in Fig. 1 which is a pyramid shape. This pie shape is normally found in the power plant or industries which use pellets as the energy fuel.

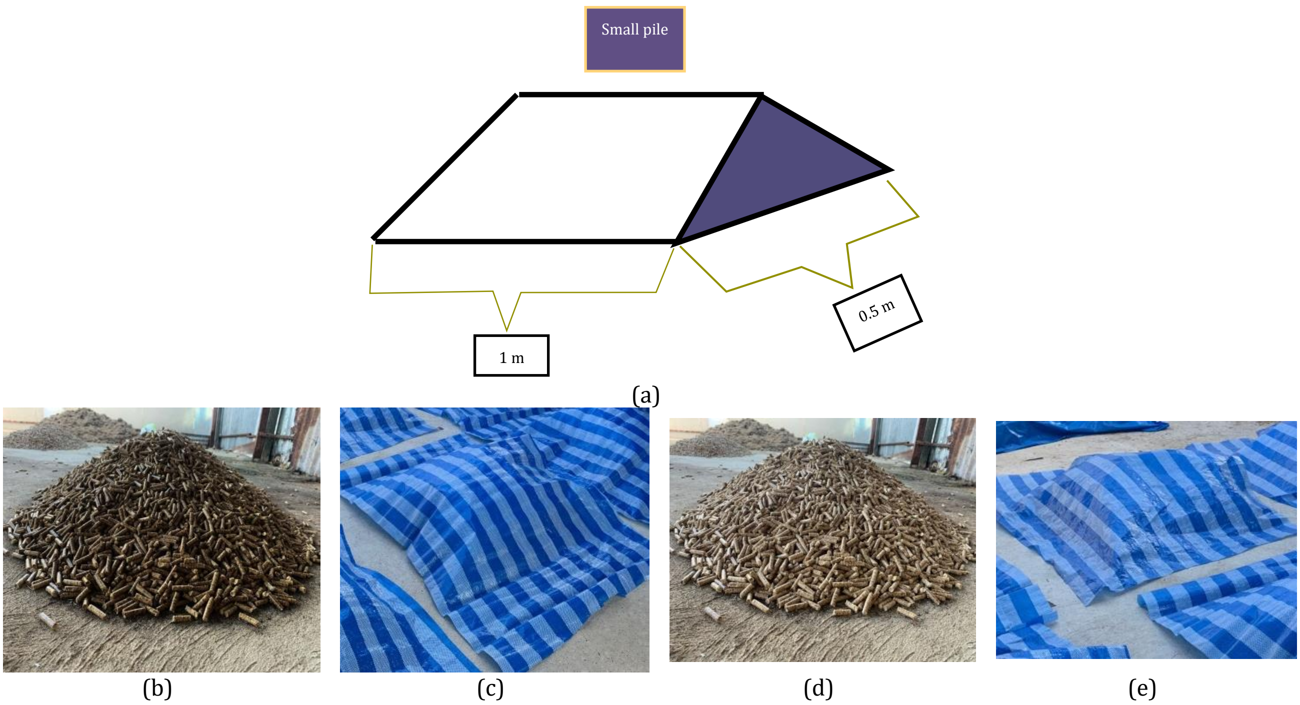


Fig. 1: Covering experiment (a) size and shape of pellet pie 1x0.5 m base by 0.35 m height, (b) uncovered torrefied wood pellet, (c) covered torrefied wood pellet, (d) uncovered torrefied corncob pellet and e) covered torrefied corncob pellet

3.2. Torrefaction process

The torrefaction process is the transformation process that can change the structure inside the pellet by reconstructing the arrangement of lignin, cellulose, and hemicellulose (Kymäläinen et al., 2015). The torrefaction process needs a high temperature (normally, 200-300°C). This experiment uses the modified furnace that can heat the pellet on the side at a temperature of approximately 250°C. The furnace and work process for this experiment are shown as Fig. 2. And the pellets (wood and corncob) before and after torrefied are represented in Fig. 3.

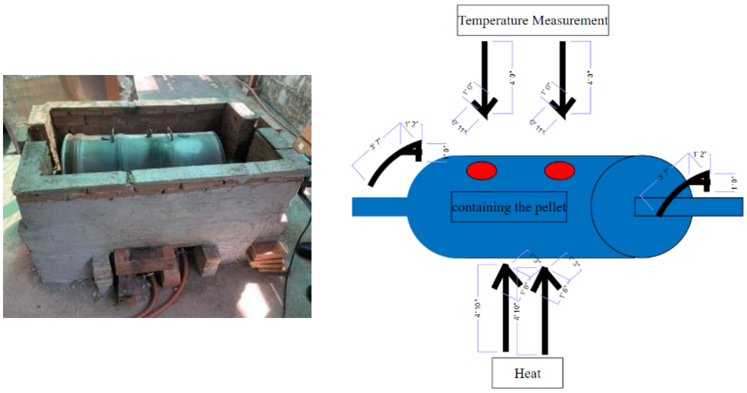
3.3. Type of pellet

The pellet is the biomass that passed through the pelletization process. It makes the biomass has a high density which has an advantage in terms of transportation and storage. This study uses 2 types of pellet for the experiment, which are wood and corncob shown in Fig. 4.

4. Result and discussion

4.1. Covering

After 6 months of storage, the result of HHV, moisture content, durability, and dry matter loss in 2 conditions of experiment with and without a covered sheet are represented in Table 1. And the trend of covered vs uncovered torrefied/black pellet of them can be illustrated in Fig. 5.



(a) (b)

Fig. 2: Torrefaction experiment (a) furnace for pellet torrefaction and (b) torrefaction process of furnace

(a) (b) (c) (d)

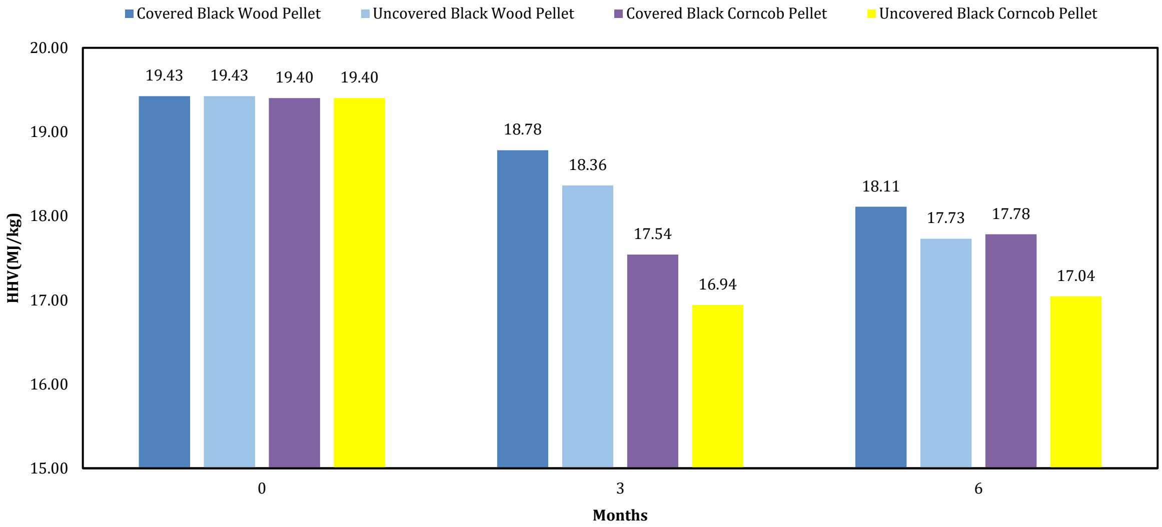
Fig. 3: (a) and (b) show the untorrefied and torrefied wood pellet and (c) and (d) show the untorrefied and torrefied corncob pellet

(a) (b)

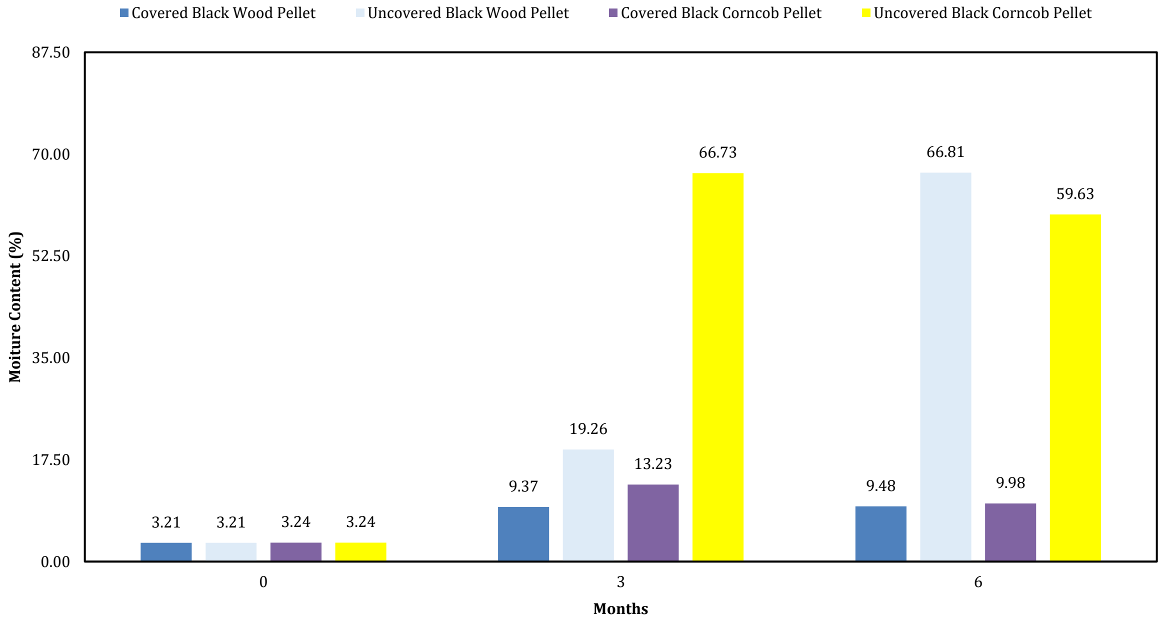
Fig. 4: The comparison of (a) wood pellet from wood biomass and (b) corncob pellet from corncob biomass

Table 1: The quantity of HHV, moisture content, durability, and dry matter loss of covered and uncovered wood and corncob pellets

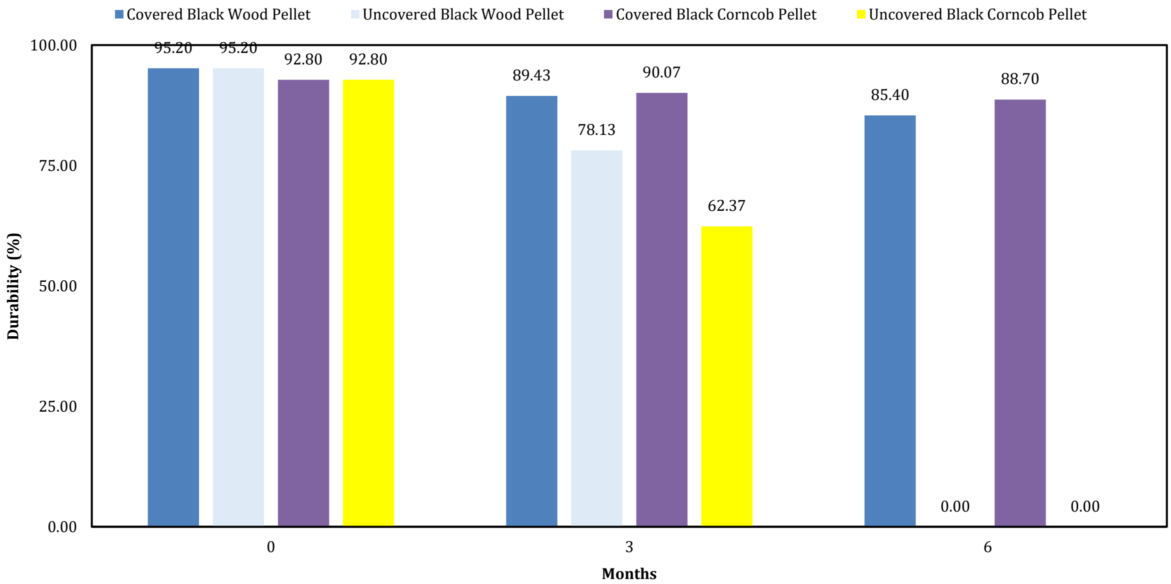
Parameters	Covering											
	Covered						Uncovered					
	Torrefied wood pellet			Torrefied corncob pellet			Torrefied wood pellet			Torrefied corncob pellet		
	0 month	3 months	6 months	0 month	3 months	6 months	0 month	3 months	6 months	0 month	3 months	6 months
HHV	19.43	18.78	18.11	19.40	17.54	17.78	19.43	18.36	17.73	19.40	16.94	17.04
Moisture Content	3.21	9.37	9.48	3.24	13.23	9.98	3.21	19.26	66.81	3.24	66.73	73.69
Durability	95.20	90.07	88.70	92.80	89.43	85.40	95.20	78.13	0.00	92.80	62.37	0.00
Dry matter loss	-	0.90	2.10	-	0.84	1.70	-	3.42	7.10	-	5.50	9.20


Covered Black Wood Pellet
Uncovered Black Wood Pellet
Covered Black Corncob Pellet
Uncovered Black Corncob Pellet
HHV(MJ/kg)
20.00
19.00
18.00
17.00
16.00
15.00
19.43
19.43
19.40
19.40
18.78
18.36
17.54
16.94
18.11
17.73
17.78
17.04
0
3
6
Months

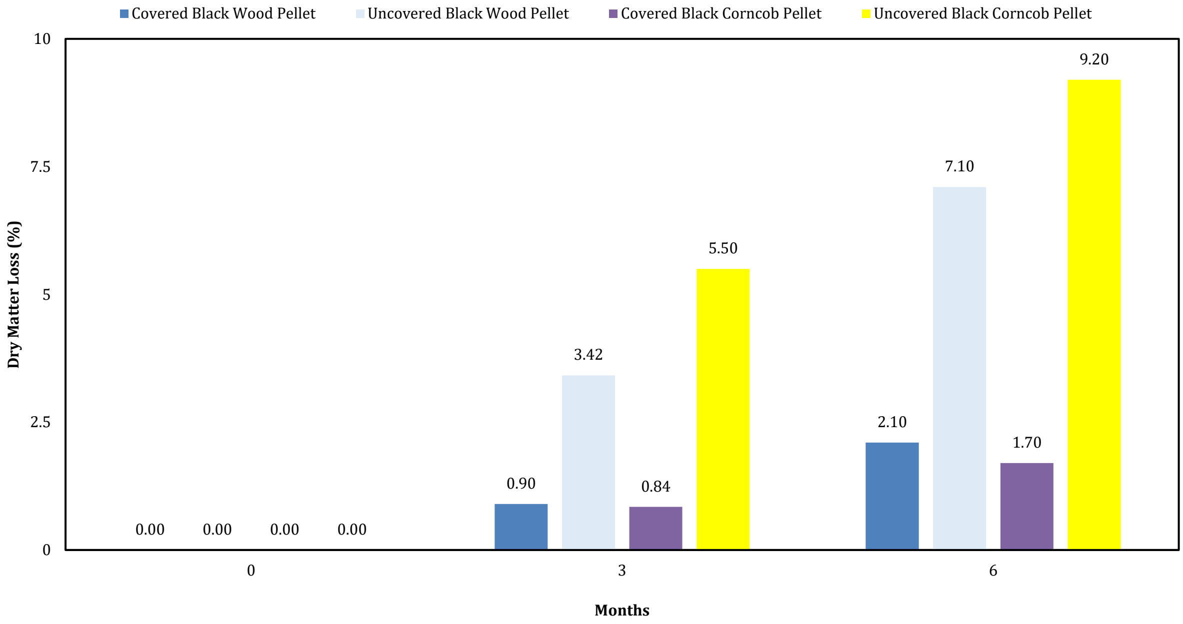
(a)


Covered Black Wood Pellet
Uncovered Black Wood Pellet
Covered Black Corncob Pellet
Uncovered Black Corncob Pellet
Moiture Content (%)
87.50
70.00
52.50
35.00
17.50
0.00
3.21
3.21
3.24
3.24
9.37
19.26
13.23
66.73
9.48
66.81
9.98
59.63
0
3
6
Months

(b)


Covered Black Wood Pellet
Uncovered Black Wood Pellet
Covered Black Corncob Pellet
Uncovered Black Corncob Pellet
Durability (%)
100.00
75.00
50.00
25.00
0.00
95.20
95.20
92.80
92.80
89.43
78.13
90.07
62.37
85.40
0.00
88.70
0.00
0
3
6
Months

(c)



(d)

Fig. 5: a)HHV; b) moisture content; c) durability; d) dry mass loss of covered and uncovered torrefied wood and corncob pellets

Table 1 and Fig. 5 illustrate the HHV, moisture content, durability, and dry matter loss of torrefied wood and corncob pellet pies which are covered by a plastic sheet and without the covering after 3 and 6 months. The HHV and durability of a covered and uncovered pellet (wood and corncob pellet) slightly decrease from start to 6 months particularly uncovered pellets. On the other hand, moisture content significantly increases for uncovered pies of pellets especially corncob the trend is similar to dry matter loss. All in all, wood and corncob pellets have a similar trend for changing HHV, moisture content, durability, and dry loss matter but corncob pellet is more humid and increases in durability than wood pellets.

4.2. Torrefaction process

After 6 months of storage, the result of HHV, moisture content, durability, and dry matter loss of two different characteristics of the structure, torrefied and untorrefied pellet are shown in Table 2 and the trend of untorrefied vs torrefied of them can be demonstrated in Fig. 6.

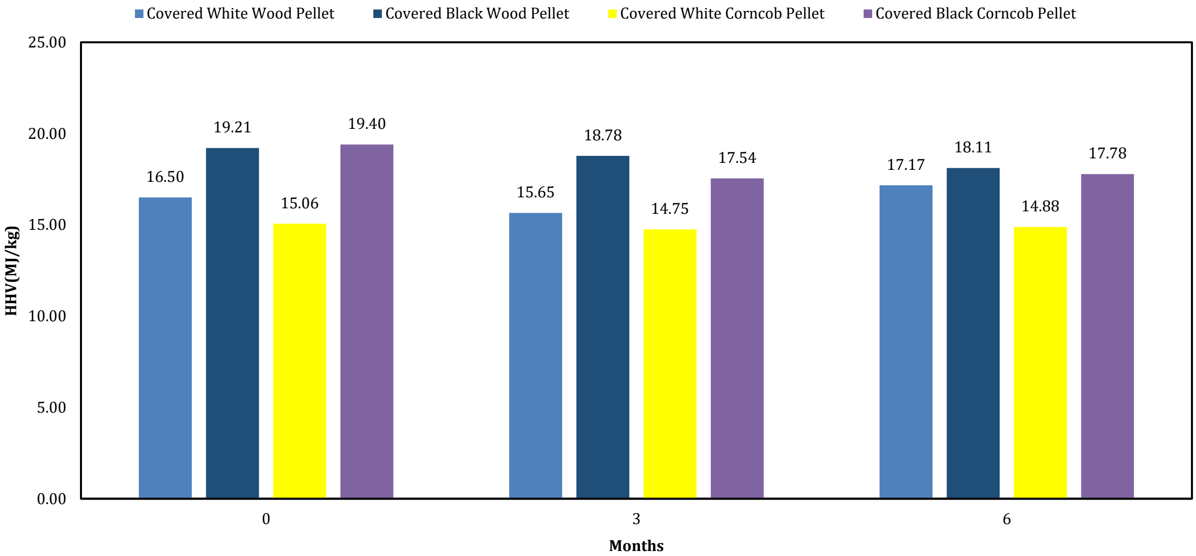
From the torrefaction experiment, Table 2 and Fig. 6 show that torrefied pellet has an HHV value more than untorrefied pellet around 1.2 times after 6 months including the moisture content of torrefied pellets also approximately increase. Furthermore, durability of both decreases after 6 months especially untorrefied pellets due to the pellets are pelletized before torrefied. Nevertheless, changing of dry matter loss of torrefied and untorrefied pellets are similar and no significant.

4.3. Type of pellet

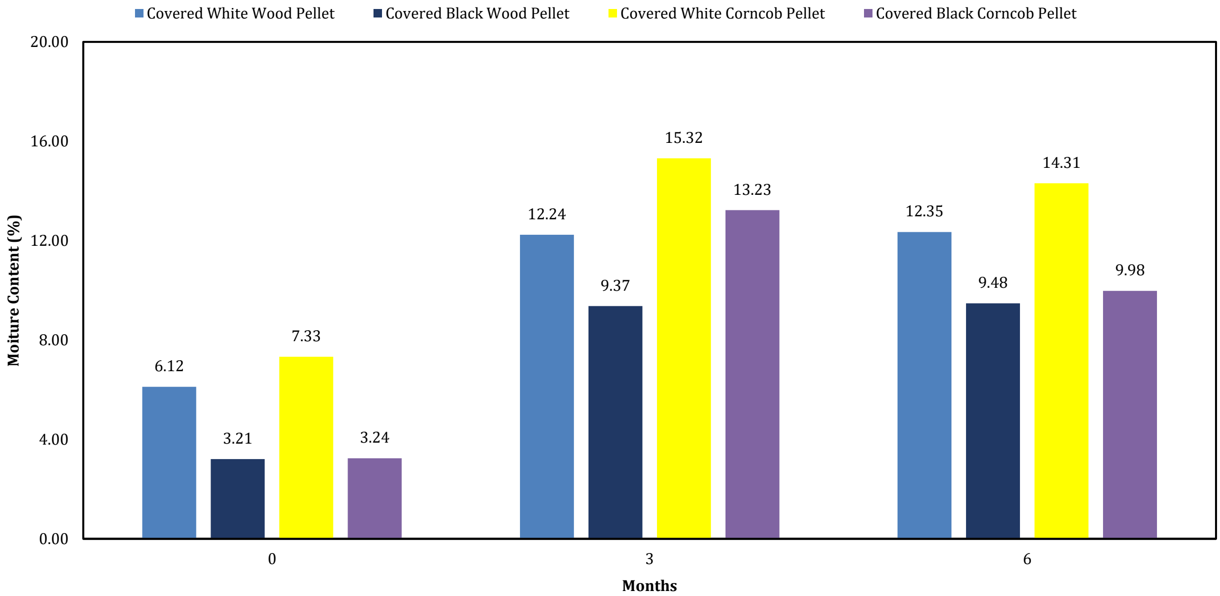
From the above experiment, the wood and corncob pellets are not different in terms of pellet quality such as HHV and moisture content that are not influenced by storage. On the other hand, the durability of the wood pellet is more than corncob pellets whether stored for 3 or 6 months. The covered pellets are better uncovered in case of HHV, moisture content, and durability.

Table 2: The quantity of HHV, moisture content, durability, and dry matter loss of torrefied and untorrefied wood and corncob pellets

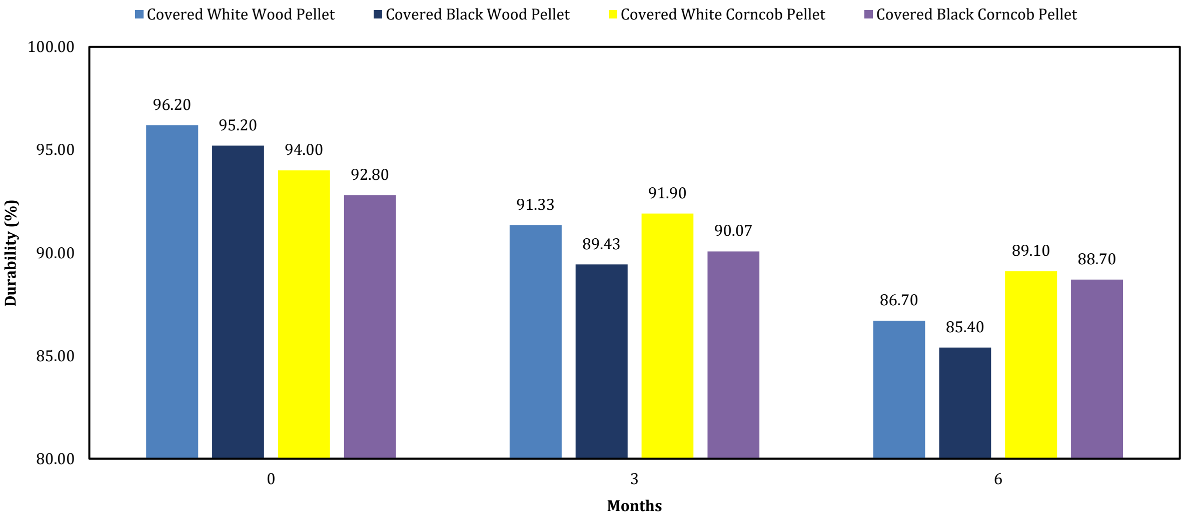
Parameters	Torrefaction											
	Untorrefied						Torrefied					
	Wood pellets			Corncob Pellets			Wood pellets			Corncob Pellets		
	0 month	3 months	6 months	0 month	3 months	6 months	0 month	3 months	6 months	0 month	3 months	6 months
HHV	16.50	15.65	16.31	15.06	14.75	14.88	19.43	18.78	18.11	19.43	18.78	18.11
Moisture Content	6.12	12.24	12.35	7.33	15.32	14.31	3.21	9.37	9.48	3.24	13.23	9.98
Durability	96.20	91.33	89.70	94.00	91.90	89.10	95.20	90.07	88.70	92.80	89.43	85.40
Dry matter loss	-	0.83	1.90	-	0.87	1.60	-	0.84	1.70	-	0.90	2.10


Covered White Wood Pellet
Covered Black Wood Pellet
Covered White Corncob Pellet
Covered Black Corncob Pellet
HHV(MJ/kg)
25.00
20.00
15.00
10.00
5.00
0.00
16.50
19.21
15.06
19.40
15.65
18.78
14.75
17.54
17.17
18.11
14.88
17.78
0
3
6
Months

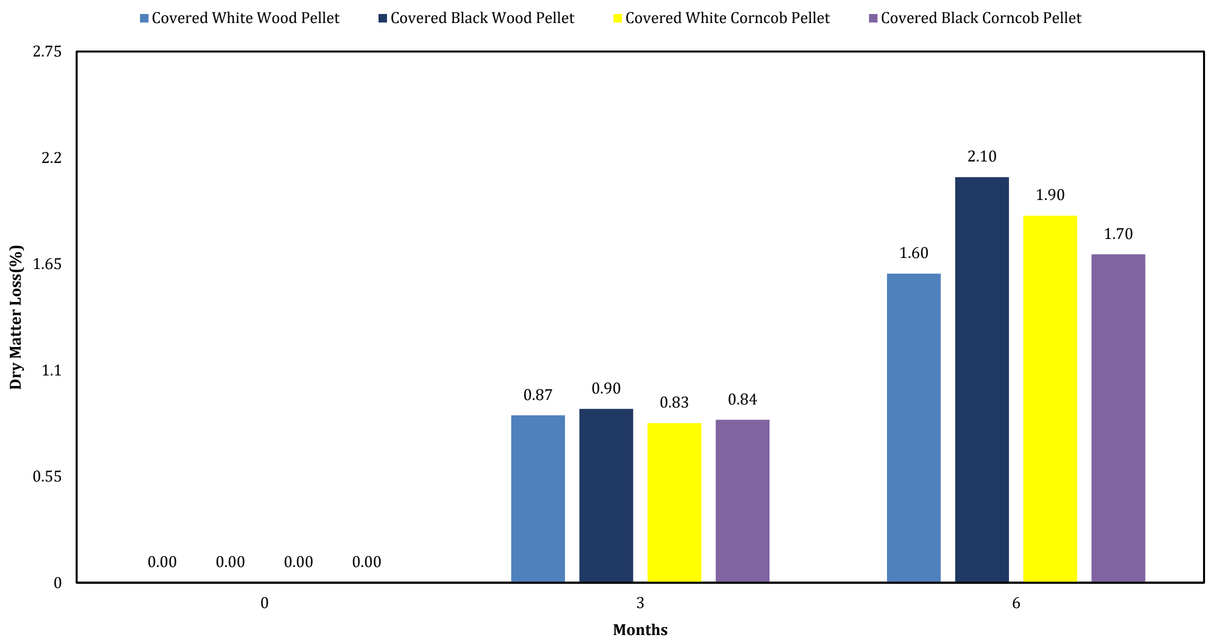
(a)


Covered White Wood Pellet
Covered Black Wood Pellet
Covered White Corncob Pellet
Covered Black Corncob Pellet
Moiture Content (%)
20.00
16.00
12.00
8.00
4.00
0.00
6.12
3.21
7.33
3.24
12.24
9.37
15.32
13.23
12.35
9.48
14.31
9.98
0
3
6
Months

(b)


Covered White Wood Pellet
Covered Black Wood Pellet
Covered White Corncob Pellet
Covered Black Corncob Pellet
Durability (%)
100.00
95.00
90.00
85.00
80.00
96.20
95.20
94.00
92.80
91.33
89.43
91.90
90.07
86.70
85.40
89.10
88.70
0
3
6
Months

(c)

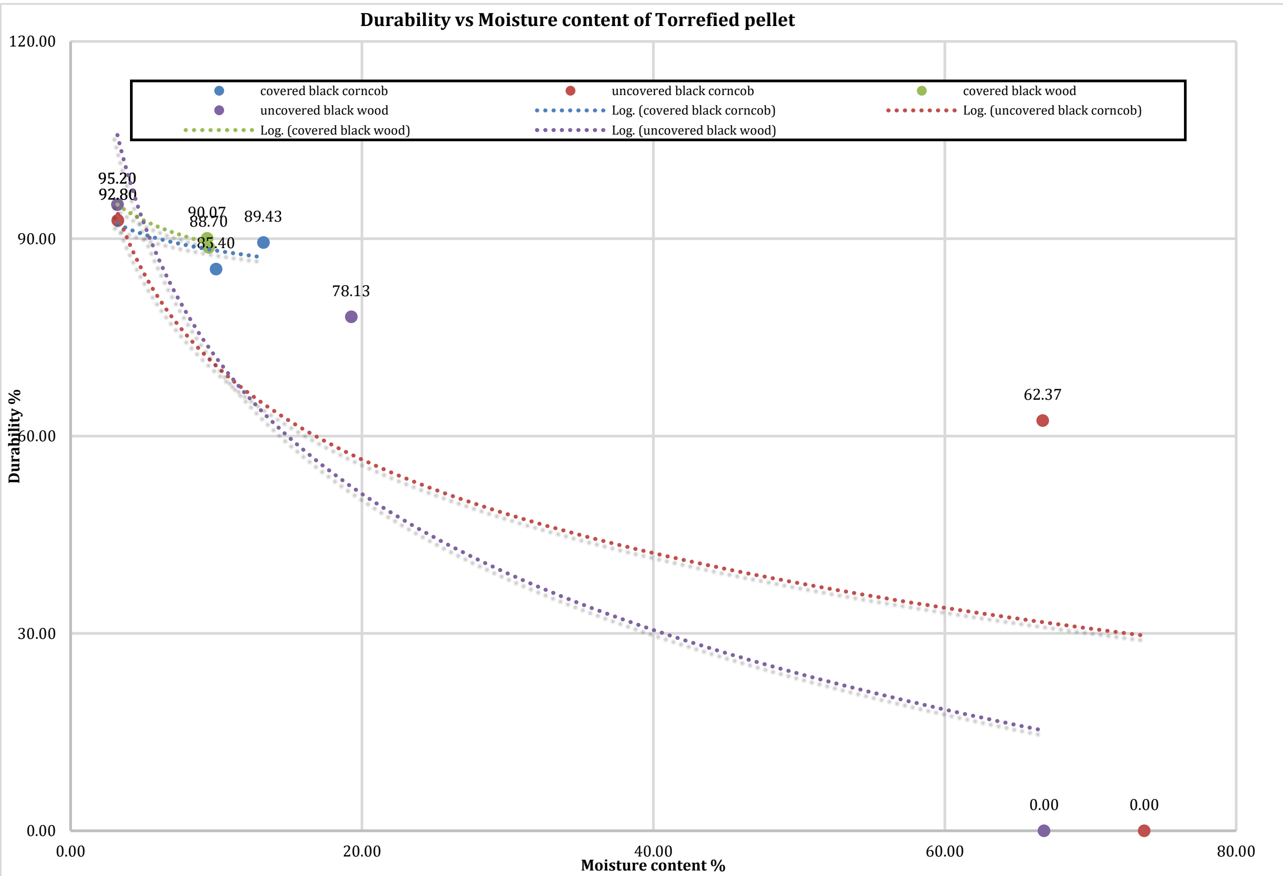


(d)

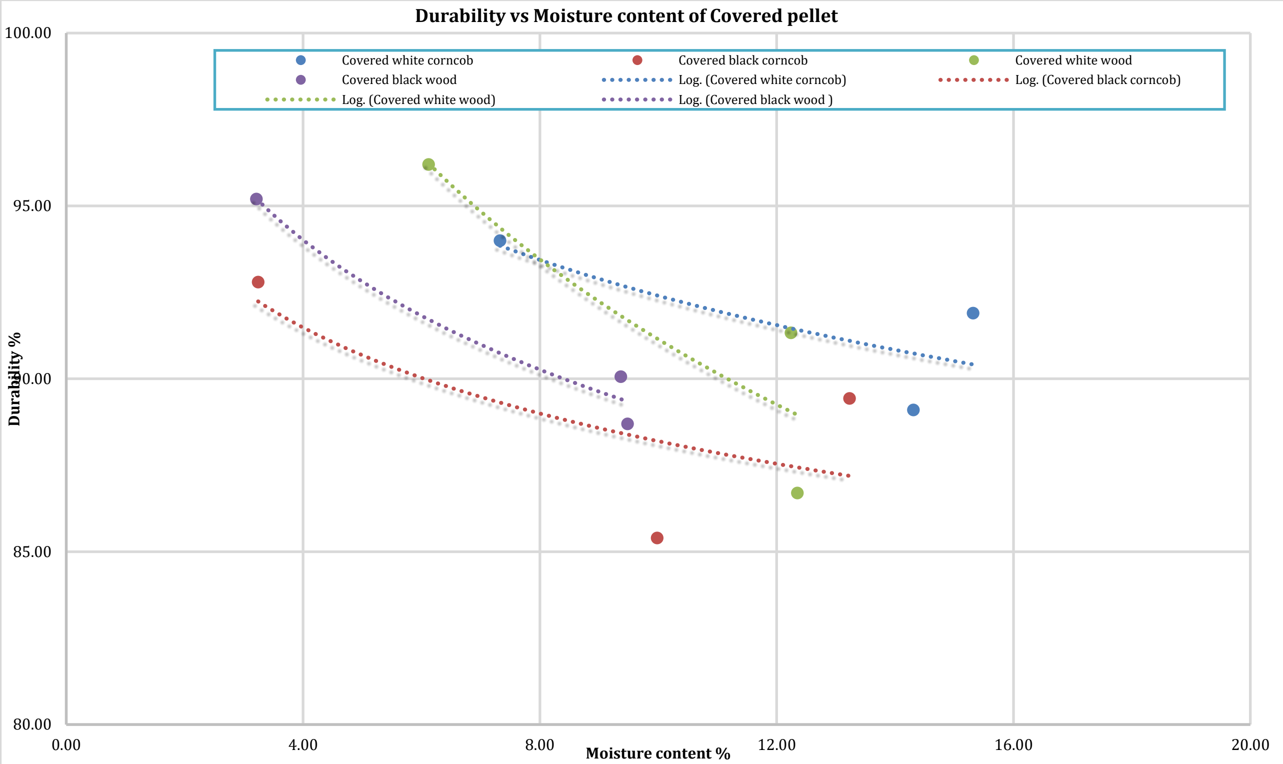
Fig. 6: a) HHV; b) moisture content; c) durability; d) dry mass loss of untorrefied and torrefied wood and corncob pellet

4.4. Durability and moisture content

From the study, the relationship between durability and moisture content shows that the pellets that are less moisture content have more durability especially covered torrefied pellets (wood and corncob) as shown in Fig. 7a. Shown in Fig. 7b, the moisture content of covered wood pellets slightly change when compared with the corncob pellets, particularly untorrefied pellets that means the untorrefied wood pellets have better quality under dry condition (covered pellet).



(a)



(b)

Fig. 7: Graph of relationship between durability and moisture content of (a) covered and uncovered torrefied wood and corncob pellets (b) covered torrefied and untorrefied wood and corncob pellets

5. Conclusion

This study is the investigation of the quality of wood pellets and corncob pellets during long-term storage covered, uncovered to be studied with and without the torrefaction process. For the HHV in the torrefaction experiment, torrefied wood and corncob pellets have higher HHV than untorrefied pellets around 15-30%. The higher HHV can be the efficient fuel that long-term storage cannot significantly reduce the HHV for both pellet types (wood and corncob pellets). For that covering process, covered and uncovered don't influence HHV. To sum up, torrefaction can significantly influence HHV only. For moisture content of each type of pellet, covered pellets have less moisture content than uncovered approximately 3% for both (wood and corncob pellets). However, wood and corncob pellets without the coversheet (uncovered pellet pies) can be a moisture content inside of around 70%. For durability that is the strength index of pellets, the durability dramatically declines when the pellets have been stored for 6 months for wood and corncob pellets whether covered or uncovered. The durability of corncob black wood and corncob pellet decreased around 95.2% in the case uncovered while in the covered case of wood and corncob, the durability declined around 7.4% and 4.1% respectively. Due to the 3rd month of the experiment which is a rainy season, it results in moisture content in the ambient air and inside pellet especially uncovered condition of pellet pile that cannot measure that durability after 6 months even it is torrefied pellets. Based on the study, the environmental condition can play the important role in the quality of the pellets. Thus, the torrefied wood pellets that are stored in dry conditions can be good quality energy fuel.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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