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Classification of Briquettes Selection Criteria Using Principal Components Analysis Approach

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Abstract

The briquettes have the potential to reduce reliance on charcoal and firewood while addressing employment issues for youths and women through briquette-making value chain components. However, the marketing that would increase the acceptance of the briquettes requires an essential understanding of the briquettes' critical selection criteria considered by potential briquette users. This study assesses the classes of briquette energy and their preferences. The study specifically investigated the following: 1) level of interest in briquette's geometric shapes, 2) classes for briquette geometric shapes 3) class components leading to purchasing the briquettes. A baseline survey was conducted, which included 330 households in the Morogoro district's urban, peri-urban, and rural communities. The study used a snowball technique to meet with respondents, especially in families with youth and women. Securing information in objectives one and two used the five Likert scales (Strongly Agree, Agree, Neutral, Disagree, and strongly disagree). In contrast, objective three utilized the five Likert scales of 1, 2, 3, 4, and 5 in the order of importance. The Principal Component Analysis (PCA) method assisted in classification and interpreting the motive behind preferences. The results found that the motive behind the shape preferences was in two categories, each including three principal components. The categories are 1) geometric shapes: round, long, and circular/plate forms, and 2) purchasing influences: performance, attractiveness, and personal capacity. Therefore, the briquettes with technically improved round shapes produced based on the performance factors are recommended for adoption and marketability.

Keywords

Preference, Biomass, Environment, Charcoal, Wastes

1. Introduction

One of the most significant difficulties confronting the world is increasing the use of green cooking energy generated from briquettes made of forest and agricultural wastes as an alternative to non-sustainable sources. The briquettes can potentially reduce such challenges and eventually solve the problem of over-reliance on charcoal and firewood [1]. In addition, the technology of briquette making is connected with the employment opportunities in its value chain components, especially for youths and women [2]. Furthermore, the briquettes provide several advantages, including consistent high energy density, ease of transportation, less smoke, and improved handling and storage, especially when biomass is appropriately densified [3]. Such advantages are reported from the agricultural and forest wastes, including groundnut shells, corn stalks, wood shavings, coffee, rice husks, cotton stalks, sawdust, and coconut residues [4] [5]. Unfortunately, such wastes are coupled with challenges of non-uniformity in energy production and unfriendly shapes for easy usage.

In Sub-Sharan Africa (SSA), forestry and agriculture generate around 1000 million tons (Mt) and 140 Mt of biomass waste each year, respectively [6]. Such vast agricultural waste may sustainably support briquette production to reduce overdependence on other unsustainable energy sources that exacerbate the environment by accumulating greenhouse gasses [7] [8]. Several studies indicate that briquette energy is useful; however, these studies have mainly relied on giving information on the briquette processing technique [9], awareness [10], machines performance [11], availability of biomass [6], and biomass performance [12] [13] [14]. Moreover, other studies highlight solutions for improving binding materials for briquette making [15], geometrical figures [16], analyzing techno-economics [17], producer workshops [18], and briquette stoves [19]. However, apart from these researchers' efforts, there are serious limited efforts toward the marketability and acceptability of the briquettes as a green energy source for cooking [20].

Increasing the acceptance and full marketing of the briquettes require an essential understanding of the briquettes' critical selection criteria considered by potential briquette users [19]. Since data sets and information gained from various studies are now dimensionally large, briquette producers face challenges identifying and comprehending specific attributes vital to consider for the briquette acceptance based on customer's key selection criteria. Furthermore, several unclassified selection criteria restrain ease of interpretation, cause information loss and poor planning. Therefore, aggregating and reducing customer selection criteria into essential aspects that may influence briquette selection positively or negatively is an important step toward increasing briquette adoption and marketability. Principal components analysis (PCA) multivariate analysis is a useful and proven method for reducing the data's complexity [3]. With this note, PCA was applied in this study to facilitate classifying the customer's selection criteria of briquette products.

Therefore, this study assesses the classes of briquette energy selection criteria and their preferences by users. Specifically, the article focuses on assessing: 1) the level of interest in purchasing briquettes depending on geometric shapes, 2) classes of influential geometric shapes for the selection of briquettes, and 3) classes of the elements leading to the purchase of the briquette products.

2. Material and Methodology

2.1. Study Area

The study was conducted in Morogoro urban, peri-urban, and rural areas, as seen in Figure 1. Chamwino, Kichangani, and Magadu were urban wards, and Mkundi, Kingolwira, and Mindu were peri-urban wards, while Kisaki, Kiroka, Kinole, and Kolero were rural wards. The Morogoro region was considered because it has significant agricultural potential, resulting in enormous biomass production. Furthermore, it is one of the top regions supplying charcoal and firewood to Dar es Salaam. Additionally, Morogoro is vulnerable to environmental degradation due to deforestation.

2.2. Materials

The authors collected the biomass briquettes of the carbonized and non-carbonized

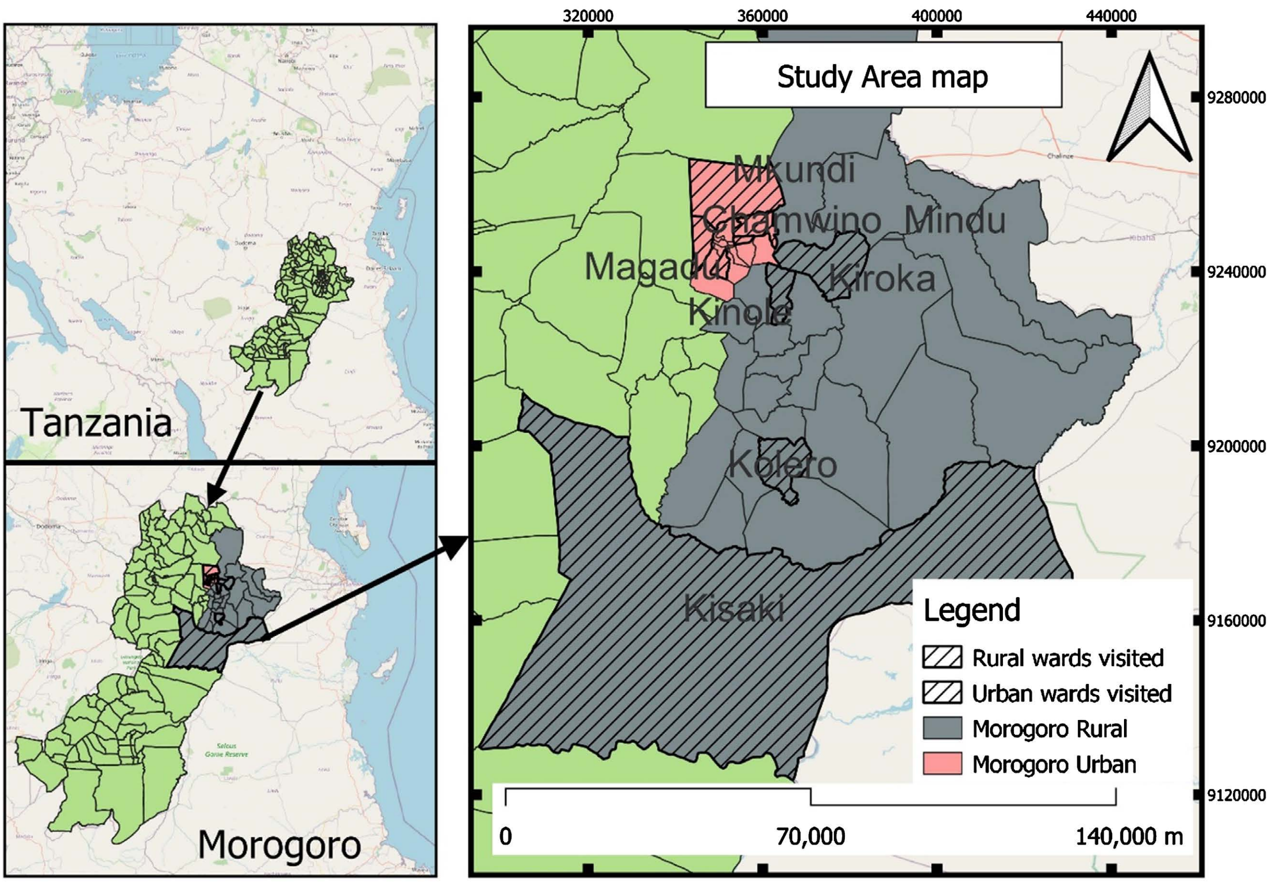

Figure 1. The map of the study area (Source: [26]).

form briquette makers in Morogoro. Furthermore, the authors revealed the collected briquettes to the respondents. For further clarification, the images of the briquettes were assembled on one A4 paper and provided an identification number. Another material involved in the baseline survey was the electronic questionnaire. This electronic questionnaire was programmed in the Geographical Open Data Kit (ODK). The enumerators loaded programmed questionnaires into the tablets and Android phones of the trained enumerators to assist in gathering data during the interview. The pre-testing of this electronic questionnaire was conducted to confirm the correctness of the questions.

2.3. Data Collection

2.3.1. Participation of Respondents

The baseline survey was conducted in households, particularly involving youths and women. The key informants surveyed were village leaders, charcoal traders, and those knowledgeable about briquette technology. These respondents were found in three urban, three peri-urban, and four rural wards. The authors randomly chose the wards from 60 Morogoro Municipality and rural district wards. In addition, among the chosen wards, 34 streets were also randomly selected. The goal was to collect at least 30 participants in each ward. A total of number 330 participants were purposefully selected using the snowball technique. The demographic profile of the respondents involved in the study is shown in **Table 1**.

2.3.2. Assessing the Level of Interest in Geometric Shapes

The respondents were shown the shapes of Stick, pillow, spherical, honeycomb, doughnut, cylindrical, and hexagonal briquette. Furthermore, the respondents were asked to rate their level of interest in each briquette shape using the five (5) Likert ratings after familiarising themselves with briquette shapes. The ratings were Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. Additionally, each respondent was asked to explain why they were interested in a particular

Table 1. Demographic profile of the respondents.

Response item	Description	Frequency (N = 330)	Respondents (%)
Age of respondent	16 - 25	158	47.9
	26 - 35	89	27.0
	36 - 45	52	15.8
	46 and above	29	9.3
Education level	Primary	203	61.5
	Secondary	88	26.7
	Tertiary	23	7
	Informal	13	3.9
	Adult	3	0.9

briquette shape by expressing that level of interest on a Likert scale.

2.3.3. Classification of the Geometric Shapes

Classification of the preference data of five (5) Likert scales (Strongly Agree, Agree, Neutral, Disagree, and Strongly disagree) to the seven (7) geometric shape components, including the Stick, pillow, spherical, honeycomb, doughnut, cylindrical, and hexagonal was done. The briquettes were logically classified, specifically based on their similarities in shape configuration. In addition, based on the similarities of geometric shape configurations within the class, the author intuitively developed an influencing factor in selecting briquettes.

2.3.4. Classification of the Elements Leading to Purchasing the Briquette

This involved rating the motivation that drives the customer when purchasing the briquettes. Sixteen (16) common components including cooking hard food, calorific value, available weight, ash content, smell, colour, appeal, briquette recipes, packaging, size, non-carbonization, carbonization, and saving the environment price, and shape, were selected based on various previous studies. The respondent was requested to rate each component based on the order of the five (5) Likert scales of 1, 2, 3, 4, and 5. The ratings were in the order of importance. Finally, the respondents were probed to state the reasons for assigning the rates to the elements to ensure they rationally do rating.

2.4. Data Analysis

The Statistical Package for Social Sciences, version IBM SPSS Statistics 20 Program, was used to perform descriptive and inferential data statistics to assess the level of interest in geometric shapes. In addition, using the Principal Component Analysis (PCA), the seven component classes based on shape configuration were formed. PCA was conducted under the Rotation of Oblimin with Kaiser Normalization at an eigenvalue of one (1) and 25 maximum iteration coverage. Furthermore, using PCA, the sixteen component classes based on drivers that motivate a customer to purchase the briquettes were created. In this case, the PCA was also conducted under the Rotation of Oblimin with Kaiser Normalization. However, the eigenvalue was set at 1.5 (**Figure 2**) for more minimization and meaningful principal components. In addition, the analysis was conducted at 25 maximum iteration coverage.

3. Results and Discussion

3.1. Level of Interest in Purchasing Briquettes Based on Geometric Shapes

The analysis was performed to establish the level of interest of respondents in purchasing briquettes as per the geometric shapes. The analytical results based on the Likert scale of "Strongly Agree", which are shown in **Table 2**, indicate that spherical and pillow were the first (52%) and second (46.4%) important shapes to the respondents, respectively, among the other shapes considered

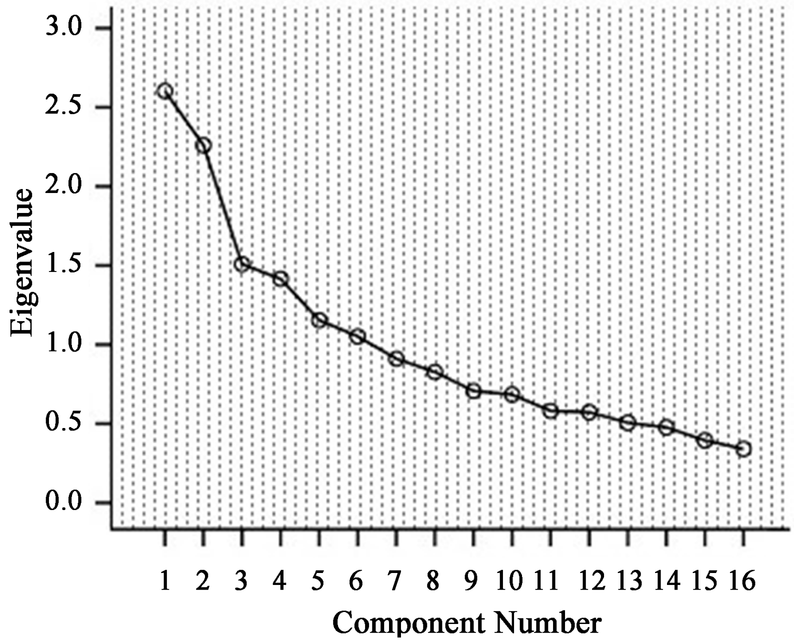

Figure 2. Scree plot indicating the selection of principal components from sixteen common elements leading to purchasing the briquette.

Table 2. Level of interest in purchasing the briquettes based on shapes.

Briquette shape type	Level of interest					Total (%)
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	
Stick	48 (14.5)	**219 (66.4)**	51 (15.5)	10 (3)	2 (0.6)	330 (100)
Pillow	**153 (46.4)**	91 (27.6)	65 (19.7)	18 (5.5)	3 (0.9)	330 (100)
Spherical	**173 (52.4)**	64 (19.4)	77 (23.3)	8 (2.4)	8 (2.4)	330 (100)
Honeycomb	36 (10.9)	77 (23.3)	**171 (51.8)**	**38 (11.5)**	8 (2.4)	330 (100)
Doughnut	32 (9.7)	92 (27.9)	**153 (46.4)**	**50 (15.2)**	3 (0.9)	330 (100)
Cylindrical	45 (13.6)	**152 (46.1)**	97 (29.4)	31 (9.4)	5 (1.5)	330 (100)
Hexagonal	33 (10)	**206 (62.4)**	67 (20.3)	19 (5.8)	5 (1.5)	330 (100)

Note: The number outside the bracket indicates the number of respondents, while the number inside the bracket shows the percentage of respondents.

during the analysis. Similar findings have been reported in Uganda, particularly for briquettes with spherical shapes [20]. Further probing of respondents provided the main reason for interest in spherical and pillow shapes. The briquette roundness increased a higher likelihood of fitting the briquettes in traditional stoves. While customers prefer round briquettes, it has been reported to ignite inefficiently due to clogging the ventilation holes of traditional stoves. [8]. Therefore, the mismatching of the consumer's interest and the challenging utilization of round objects in the traditional cooking stoves might be one of the challenges in hindering the adoption

Furthermore, based on the Likert scale of "Agree", **Table 2** shows that the Stick (66.4%), hexagonal (62.4%), and cylindrical (46.1%) shapes were the first and second leading shapes based on the interest of the respondents. In addition, the "Neutral" Likert scale reveals that the honeycomb (51.8%) and doughnut (46.4%) were consecutively prominent. These shapes were chosen because they resemble charcoal and firewood. They are consistent in size, have an excellent combustion frame over their surface area, and may release energy more quickly [20]. Besides, they are likely to be easily scaled to accommodate conventional stoves. In this study, the Stick shape was not perforated, while the hexagonal and cylindrical briquettes were perforated to increase the ignition performance [21] [22].

Moreover, respondents preferred non-perforated stick forms over perforated hexagonal and cylindrical designs. One rationale for choosing non-perforated shapes over perforated briquettes is likely since the respondents mostly use charcoal, which is generally not perforated, resulting in limited exposure to combustive air during its utilization. Furthermore, when considering the possibility of hand-made briquettes, respondents found it difficult to imagine creating perforated briquettes in their households.

In addition, on the Likert scale of "Neutral" or "Disagree", the Honeycomb and the Doughnut were also prominent with higher percentage scores than other shapes (**Table 2**). The absence of suitable arrangements in local cooking stoves is likely the cause of these uninteresting scores. Besides, the honeycomb contained many holes, whereas the doughnut just had one, which served as a source of improved ignition around the surface. However, the increased ignition on such a configuration could not sway the respondents, who are potential users. The results did not indicate any geometric shape, with a significant percent score on the Likert scale of "Strongly disagree".

3.2. Classification of Influential Geometric Shapes for the Selection of Briquettes

The findings on the classification of geometric shapes of briquettes using the Principal Component Analysis (PCA) are shown in **Table 3**. Using the PCA technique, the briquettes' seven geometric features were classified into three main components that are PCA1, PCA2, and PCA3. In addition, the table shows a low correlation between PC1 and PC2, PC1 and PC3, and PC2 and PC3 at −0.031, 0.11, and −0.058, respectively. Besides, at least 40% ($R^2 > 0.4$) of information regarding each geometric briquette shape characteristic was explained during loading.

Referring to **Table 3** and the column with PCA1, the Doughnut and Honeycomb were found substantially close with a significant loading weight of 0.778 and 0.639, respectively, compared to the other geometric features. These shapes were loaded together because of their similar appearance. The results triggered the authors intuitively to consider these geometries being in the form of a plate. Therefore, the general factor deduced under PCA1 was Circular/plate shape geometry. However, in **Table 2**, these shapes scored high on the Likert scale of neutral and disagree.

Table 3. Principal component analysis results of briquette geometric shapes based on loading weight score.

Briquette shape type	Principal component			Communality Extracted Value R^2
	PCA1	PCA2	PCA3	
Doughnut**	**0.778**	0.169	−0.124	0.418
Honeycomb**	**0.639**	0.014	0.164	0.562
Stick⁺⁺	−0.456	**0.437**	−0.033	0.642
Cylindrical⁺⁺	0.169	**0.764**	−0.165	0.458
Hexagonal⁺⁺	0.011	**0.752**	0.179	0.621
Spherical ##	−0.054	0.092	**0.806**	0.641
Pillow##	0.091	−0.064	**0.728**	0.582
Correlation	PC1 & PC2 −0.031	PC1 & PC3 0.11	PC2 & PC3 −0.058	–

** = Neutral interest, shapes in plate form, ++ = Agree interest, shapes in certain length, and ## = Strongly agree interest, shapes near to round, PC = principal component, PCA = principal component analysis.

The results in Table 3 in the column of PCA1 show that Doughnut (0.778) and Honeycomb (0.639) preference loadings are inversely correlated to the preference for stick briquettes (-0.456). Therefore, according to this inverse correlation, when consumers are either neutral or disagree with plate-shaped briquettes, their interests may shift towards longer briquettes.

In the column of PCA2, the high loading weights of 0.437, 0.764, and 0.752 were found in three geometric shape features, which are Stick, Cylindrical, and Hexagonal, respectively. Intuitively, the authors observed that these three geometric shapes were combined likely because of being lengthy. The first and most common assumption stated by respondents when selecting long briquettes is that they will burn effectively as they are long like charcoal and firewood.

In the column with PCA3, the loading mainly included the Spherical and Pillow at 0.806 and 0.728 loading weights, respectively. The authors considered these two geometric shapes to be grouped together due to their roundness configuration. Although the configuration is technically inefficient in the ignition [8], briquettes in the roundness factor were strongly agreed upon by most respondents (Table 2). The majority of spherical briquettes, which fall in the roundness configuration, have been reported to be produced by hand compression, particularly by women [20]. The preference on roundness factor might also be connected to other benefits, such as the ease with which briquettes can be made at home and purchased at a lower cost.

3.3. Classification of Elements Leading to Purchasing the Briquette Products

The PCA results of classifying the elements that lead to purchasing the briquette products are shown in **Table 4**. The table shows that elements were grouped into three principal components analysis (PCA_1, PCA_2, and PCA_3). The authors logically grouped the motivation elements in PCA_1 as "performance factor/component" (PC_1), while the motivations in PCA_2 and PCA_3 were grouped as "attractiveness component" (PC_2) and "personal capacity component" (PC_3), respectively. The motive element was included in the principal factor/component in the PCA column if it met the loading-weight score requirement of at least 0.4.

Furthermore, the results in the table showed that PC_1 and PC_2 are positively correlated (correlation value = 0.059). This phenomenon indicates that PC_1 and PC_2 positively motivate purchasing the briquette. Similar results are noted for both PC_1 and PC_3, where the correlation of these factors is positive (correlation value = 0.065). In addition, the PC_2 and PC_3 are also positively correlated (correlation value = 0.095). Therefore, the presence of motives of PC_2 positively and

Table 4. Factor analysis for motivation and concern of client when deciding to purchase the briquette products based on loading weight score.

Type of Motivation	N = 330 Max. SCORE (Frequency %)	Principal components			Extraction coefficient R^2
		PCA_1	PCA_2	PCA_3	
Cooking hard food	100 (42.7)	**0.743**	−0.174	−0.12	0.521
Calorific value	100 (56.1)	**0.685**	0.052	0.167	0.574
Easily available	100 (53.0)	**0.651**	0.002	−0.07	0.599
Weight	100 (52.4)	**0.588**	−0.29	0.425	0.424
Ash content	40 (24.2)	**0.530**	0.393	−0.372	0.545
Smell	80 (25.8)	**0.412**	0.151	0.075	0.212
Colour	40 (20.3)	−0.134	**0.747**	−0.036	0.561
Appealing	60 (18.8)	0.068	**0.736**	−0.219	0.568
Briquetting recipes	40 (31.5)	0.132	**0.522**	0.003	0.299
Packaging	40 (28.5)	−0.027	**0.528**	0.16	0.319
Size	60 (28.5)	0.001	**0.467**	0.33	0.357
Non-carbonization	40 (37.9)	0.051	−0.15	−0.276	0.106
Carbonization	100 (45.2)	0.129	0.152	**0.404**	0.223
Saving environment	100 (51.8)	0.283	−0.139	**0.698**	0.589
Price	100 (40.9)	−0.045	−0.147	**0.433**	0.594
Shape	100 (35.8)	−0.095	0.288	**0.417**	0.486
Correlation		PC_1 & PC_2 0.059	PC_1 & PC_3 0.065	PC_2 & PC_3 0.095	
PCA Remark		Performance factor	Attractiveness factor	Personal capacity factors	

PC = principal component.

likely impacts PC_3 motivations for purchasing the briquettes. Based on the motivation loading weight scores, the elements creating the principal component in the PCA_1 were superior to major motivation elements under PCA_2 and PCA_3.

The elements under PCA_1 that influenced respondents' motivation to purchase briquettes included the ability to cook hard food, calorific value, ash content, smell, and availability. These explain the performance of utilizing the briquette. Previous research has shown a similar situation regarding some of these features. However, the information on whether they join together to make a top priority for consumers, as shown in PCA_1, was limited. For instance, complaints related to a large volume of ashes and low calorific value were raised [23]. Besides, the availability and smell were noted in the work of [24] and [25].

Additionally, the colour, appeal, briquette formulations, packaging, and size impacted the PCA_2. Therefore, the PCA_2 was chosen as an attractive factor since most of its elements may be evaluated based on their appearance. In addition, the PCA_3 was considered to be the personal capacity factor. This factor comprised a customer's declared motive, specifically on non-carbonized briquettes, carbonized briquettes, saving of environment, low cost, and shape of briquettes.

Moreover, it is assumed that the elements in PCA_3 are related to a personal capacity because the briquette developers may have little control to make them suitable for a customer. For example, a client with a conventional cooking stove may be incapable of utilizing a specific briquette shape unless they have a standard briquette burner. Customers who use firewood may be motivated by non-carbonized briquettes because they resemble firewood, but those who use charcoal may be motivated by carbonized briquettes. The capacity to purchase also depends on personal ability. The issue of saving the environment also may depend on personal attitudes.

In addition, the results through probing revealed that the respondents were aware of the firewood and charcoal being the significant contributors to environmental degradation. The respondents stressed replacing firewood and charcoal with environmentally friendly energy sources. Lastly, several respondents did not show concern about the cost of purchasing the environmentally friendly source of energy, the briquettes.

4. Conclusions and Recommendation

4.1. Conclusions

Applying the principal components analysis method in this study reveals that this method is a vital approach for assessing the potentiality of classifying the key briquettes selection criteria into essential factors. The factors are easily interpreted to facilitate any briquette-making planning, adoption, and marketing. Furthermore, the spherical and pillow shapes, which are in the round form shapes, are the most important geometric shapes that positively influence the interest in purchasing briquettes. However, briquettes with these shapes are technically inefficient in their utilization [8]. In addition, the honeycomb and the doughnut shapes negatively influence the interest of potential customers of the briquettes.

The influential geometric shapes for selecting briquettes fall into three classes: shapes in plate, lengthened, and rounded forms. The rounded-form shapes are the most influential shapes for selecting the briquette. In addition, classifying the elements leading to the purchase of the briquette products produces three classes that are based on the performance, attractiveness, and personal capacity factors. The class based on the performance factor/component is superior to the other two classes regarding the motivation to purchase the briquette products. Furthermore, environmental degradation due to firewood and charcoal utilization is known at the study site. Also, the cost of purchasing briquettes as an environmentally friendly energy source is not considered a hindrance factor in adopting the briquettes.

4.2. Recommendation

This study classified the common influential variables that contribute to briquette selection once presented to the potential briquette costumers. The principal components analysis approach applied in classifying the variables is recommended to other researchers and project developers facing similar challenges in classifying variables. Additionally, the authors recommend the production of the briquette with the spherical and pillow shapes (rounded-form), and considering the briquette performance factors to facilitate the adoption and marketability of the briquettes. However, the briquettes with the honeycomb and doughnut shapes should be improved as they are less attractive to potential customers. Finally, improving the efficient utilization of the briquette with round form shapes is a point of research interest.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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