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Data Mining Techniques: New Method to Identify the Effects of Aquaculture Binder with Sardine on Diets of Juvenile *Litopenaeus vannamei*

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Abstract: In this research, a dataset of growth performances and nutritional composition of juvenile *Litopenaeus vannamei* after being fed two diets that include aquaculture binder with sardine for 7 weeks was analyzed using data mining techniques: the K-Means Clustering Algorithm and PCA Biplot, to have a visualization of each parameter (vector) measured. The parameters evaluated were: weight gain, specific growth rate, feed efficiency, protein efficiency ratio, survival percent, moisture content, crude protein, crude lipid, and ash content. Data mining tools showed the juvenile *Litopenaeus vannamei* fed with mixture 2 (pellets mixed with the binder of sardine subproducts) presented the highest growth performances and nutritional composition, 23 juvenile *L. vannamei* shrimps showed higher relation with crude protein and crude lipid, 30 *L. vannamei* shrimps presented higher relation with ash, and 37 juvenile *L. vannamei* shrimps showed higher relation with ash and moisture. The results obtained in experimental procedures indicate that the use of a binder of sardine subproducts in shrimp diets improves the commercial parameters, improving the aquaculture field.

Keywords: aquaculture; binder of sardine subproducts; *Litopenaeus vannamei*

1. Introduction

Ecuador is considered one of the most important countries for shrimp production. There is a growing interest in expanding aquaculture using alternative species and technologies [1,2]. Aquaculture is the second largest component of the Ecuadorian economy, after fossil fuels [3]. This expansion is almost entirely attributable to shrimp aquaculture and has led to land use or land cover transitions in Ecuadorian estuaries, with historic mangroves and other estuarine land to be used as shrimp ponds [4]. The highest production of shrimp in Ecuador is due two factors: Ecuador shrimp production has traditionally been semi-intensive, using feed and water exchange but no aeration, and there is much uninhabited land suitable for large ponds and farms in Ecuador [5]. By the end of 2009, the country had 175 thousand hectares of active shrimp farms representing 2578 aquaculture companies, with an export production of 450 million pounds representing 34% of the total manufactured products [6]. The increase in shrimp farming activity has also represented a great source of work in the country [7]. In order to diversify aquaculture production in Ecuador, several projects have been carried out for the production of shrimp, *Litopenaeus stylirostris* [8], *Sciaenops ocelatus* [9], and *Seriola rivoliana* [10]. Ecuador produced 510,000 metric tons of white shrimp (*Litopenaeus vannamei*) in 2018 [11].

In 2002, as a consequence of the white spot syndrome, alternative shrimp production methods were developed, such as culture in covered ponds that allowed reduced water exchange and a more constant temperature level and the so-called "onshore" system, which consisted of cultivating shrimp at very low salinities using water from wells and rivers in agricultural areas of the provinces of Manabí and Guayas. Supplementary feeding is associated with this activity, which influences the cost of shrimp production [12]. The strategy and the optimization of the feeding are aspects of importance in aquaculture that imply the formulation of different diets (pellets). The nutrient content present in pellets will influence shrimp growth, survival, and excreted waste products [13]. In the formulation of pellets, it is necessary to maintain the valuable dietary nutrients using binders [14]; binders affect pellet stability in three ways: by reducing voids, resulting in a more compact and durable pellet acting as adhesives, sticking particles together, and exerting a chemical action on the ingredients and altering the nature of the feed, obtaining a more durable pellet [15]. Binders are used to reduce the leaching of medication applied to balanced foods and drugs such as antibiotics, vitamins, organic acids. This type of product as a mixture of gluten in the diet can be used to obtain the highest values of apparent protein digestibility (ADP) and apparent dry matter digestibility (ADMD) [16]. The use of binders as attractants in shrimp feed is not common. In order to illustrate adequate visualization, it is necessary to use data mining tools, such as K-means clustering algorithm and PCA Biplot, to study the benefits of binders in the shrimps' diets.

Data mining refers to the process of extracting knowledge from databases by discovering anomalous situations, trends, patterns, and sequences in the data. Data mining is a stage within the complete knowledge discovery process that tries to obtain patterns or models from the collected data. The algorithms of data mining techniques usually have three components: (1) The model contains parameters to be set from the input data, (2) the preference criterion compares alternative models, and (3) the search algorithm is similar to other artificial intelligence programs [17]. There are various data mining techniques that describe the interesting relationship between different attributes, such as the K-Means Clustering Algorithm and PCA Biplot [18,19].

The main goal of this study was to use data mining techniques such as the K-Means Clustering Algorithm and PCA Biplot, identifying the growth performance and the nutritional composition of juvenile *Litopenaeus vannamei* shrimps after feeding diets that include an aquaculture binder with sardine.

2. Materials and Methods

2.1. Experimental Design

Ten juvenile *Litopenaeus vannamei* shrimps (0.70 g) were randomly distributed per tank (total 180 tanks of 20 L capacity). The experiment was realized at the Shrimp Farm "La Chorrera" [20,21].

2.2. Preparation of the Mixtures

The two mixtures used in the experiment were made using the following composition:

Mixture 1 (M1): Pellets mixed with the binder (hydrolyzed of sardine subproducts 20%). The formulation was 200 mL of sardine binder on 2 L of water for 25 kg of pellets.

Mixture 2 (M2): Pellets mixed with the binder (hydrolyzed of sardine subproducts 30%). The formulation was 200 mL of sardine binder on 2 L of water for 25 kg of pellets.

2.3. Experimental Diets and Feeding

Ten juvenile shrimps were randomly distributed per tank (180 tanks), and the juvenile shrimps were fed four times a day. In the feeders were put 200 g of mixture (M1) or 200 g of mixture (M2). The shrimps were fed four times a day at the following times: 09:00 a.m., 11:30 a.m., 2:00 p.m., and 4:30 p.m., and the faeces were removed every day. Tests were performed for seven consecutive weeks [22]. The experiments were realized in triplicate.

2.4. Growth Performances of Juvenile Shrimps

Three shrimps from each tank were counted, weighed, and measured (after seven weeks of the feeding trial) to determine: growth performance including weight gain (*WG* %), specific growth rate (*SGR* %), feed efficiency (*FE* %), protein efficiency ratio (*PER*), and survival percent (*S* %) using the following equations [23,24].

$$WG\ (\%)\ =\ \frac{final\ weight\ (g)\ -\ initial\ weight\ (g)}{initial\ weigth\ (g)}\ \times\ 100 \tag{1}$$

Equation (1). Weight gain of juvenile shrimps.

$$SGR\ (\%)\ =\ \frac{ln\ final\ weight\ (g)\ -\ ln\ initial\ weight\ (g)}{days} \tag{2}$$

Equation (2). Specific growth rate of juvenile shrimps.

$$FE\ (\%)\ =\ \frac{final\ weight\ (g)\ -\ initial\ weight\ (g)}{feed\ ration\ (g)}\ \times\ 100 \tag{3}$$

Equation (3). Feed efficiency of juvenile shrimps.

$$PER\ =\ \frac{wet\ weight\ gain\ (g)}{protein\ intake\ (g)} \tag{4}$$

Equation (4). Protein efficiency ratio of juvenile shrimps.

$$S\ (\%)\ =\ \frac{final\ number\ of\ fish}{initial\ number\ of\ fish}\ \times\ 100 \tag{5}$$

Equation (5). Survival percent of juvenile shrimps.

2.5. Nutritional Composition of Juvenile Shrimps

A proximate analysis of samples was performed according to the Association of Official Analytical Chemists (AOAC). The moisture was determined by drying shrimp samples at 100 °C to constant weight. Nitrogen (N) was determined using the Kjeldahl method, and the protein content was calculated using the 6.25 factor. The soxhlet method was used to determined crude lipid. The ash content was measured by heating the samples at 600 °C for 24 h [25–27]. All test analyses were realized in triplicate per experimental diet.

2.6. Statistical Analysis

The data-mining techniques (K-Means Clustering Algorithm and PCA Biplot) were realized using R software version 4.1.1. (R Core Team, Vienna, Austria) .

K-Means Clustering Algorithm

The K-Means algorithm consists of grouping a set of data (M blocks or sample vectors extracted from the training set) in groups or clusters (K quantization cells, such that $K < M + 1$), so that the vectors of the same group present high similarity to each other and have little similarity with vectors from other groups. This technique indicates that each training vector (block of samples from the original dataset) belongs to one and only one quantization cell.

Let X = {$\sim x_j$}, $j = 1, 2, \ldots, M + 1$ be a training set composed of M vectors N-dimensional, with $M \gg K$. The K-Means algorithm divides the vector space R^N assigned to each training vector to a single cluster via Nearest Neighbor Search (*VMP*). Precisely, $\vec{x_j}$ will belong to the group (cell of quantization) V ($\vec{w_i}$ if d ($\vec{x_j}$, $\vec{w_i}$) < d ($\vec{x_j}$, $\vec{w_a}$), ∀a ≠ i, where d ($\vec{x_j}$, $\vec{w_i}$) denotes the quadratic Euclidean distance between $\vec{x}_j$ and $\vec{w}_i$. In this case, $\vec{w}_i$ is said to be the *VMP* of $\vec{x}_j$. The *VMP* search can be associated with a membership function, defined by

$$\mu_i\left(\vec{x}_j\right) = \begin{cases} 1, \; if \; \vec{w}_i = VMP\left(\vec{x}_j\right) \\ 0, \; otherwise \end{cases}$$

Thus, the distortion obtained by representing all the vectors of the training set by the respective *VMP*s is given by

$$J_1 = \sum_{i=1}^{K} \sum_{j=1}^{M} \mu_i\left(\vec{x}_j\right) d\left(\vec{x}_j, \vec{w}_i\right)$$

To minimize J_1, the vectors $\vec{w}_i$ are updated as follows:

$$\vec{w}_i = \frac{\sum_{j=1}^{M} \mu_i\left(\vec{x}_j\right) d\left(\vec{x}_j\right) \vec{x}_j}{\sum_{j=1}^{M} \mu_i\left(\vec{x}_j\right)}, \; i = 1, 2, \ldots, K$$

After initializing the $\vec{w}_i$ vector set, i = 1, 2, . . . , K, the K-Means algorithm can be summarized as follows:

1. Partitioning—the training set is partitioned into K clusters according to the *VMP* rule.
2. The new code vectors are the centroids of the clusters, calculated according to Equation $\vec{w}_i$.
3. Convergence test—algorithm stop criterion.

The partitioning and updating steps are carried out until the stop criteria is satisfied. Precisely, the algorithm stops at the end of the tth iteration if

$$\frac{J_1(t-1) - J_1(t)}{J_1(t)} \leq \in,$$

where $\in$ is an algorithm parameter, called distortion threshold, and $J_1(t)$ denotes a distortion obtained in the partitioning of the tth iteration [28].

Additionally, a PCA Biplot [29] was applied to explore and visualize the different parameters and the most relevant responses.

3. Results and Discussion

The focus of this work was to determine the viability of the use of aquaculture binder with sardine on diets of juvenile *L. vannamei* shrimps and to assess its influence on commercial parameters: weight gain, specific growth rate, feed efficiency, protein efficiency ratio, survival percent, moisture content, crude protein, crude lipid, and ash content.

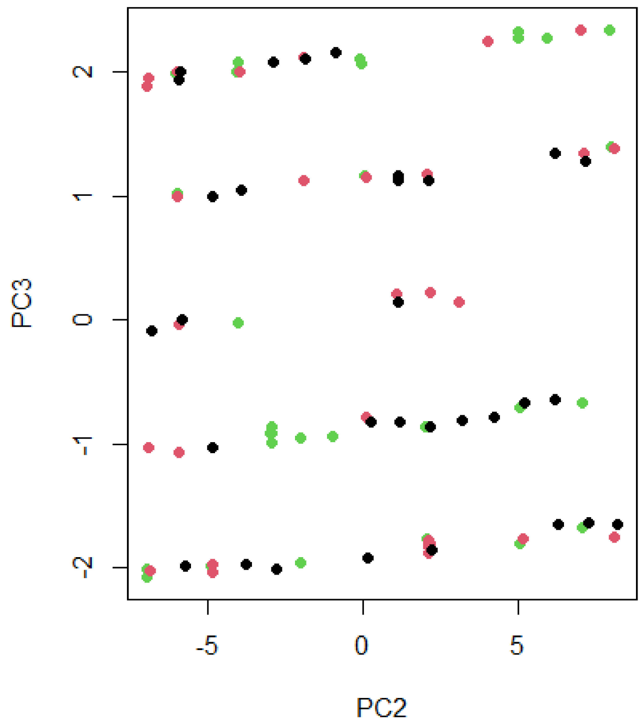
The numeration of the juvenile *L. vannamei* shrimps per tank was made following the next distribution:

1–90: Average of three juvenile *L. vannamei* shrimps per tank fed with the mixture M1 or M2 after seven weeks.

3.1. Data Mining for Growth Performances of Juvenile Shrimps

Figure 1 presents the use of method K-means clustering algorithm to 90 objects having 5 variables each, using the software RStudio. The graphic (a) presents the use of three clusters to growth performances of juvenile *L. vannamei* shrimps fed with the mixture M1 after seven weeks, while in the graphic (b) the use of three clusters to growth performances of juvenile *L. vannamei* shrimps fed with the mixture M2 after seven weeks was also presented. The results show the normal distribution of 90 data points around three clusters in each graphic. The color of the different clusters showed the specific samples that presented the highest characteristic measured. Clusters allow separation of a set of objects into none-overlapping subsets; the objects in the cluster are similar and dissimilar with the objects in the other cluster [30].

(**a**)



(**b**)

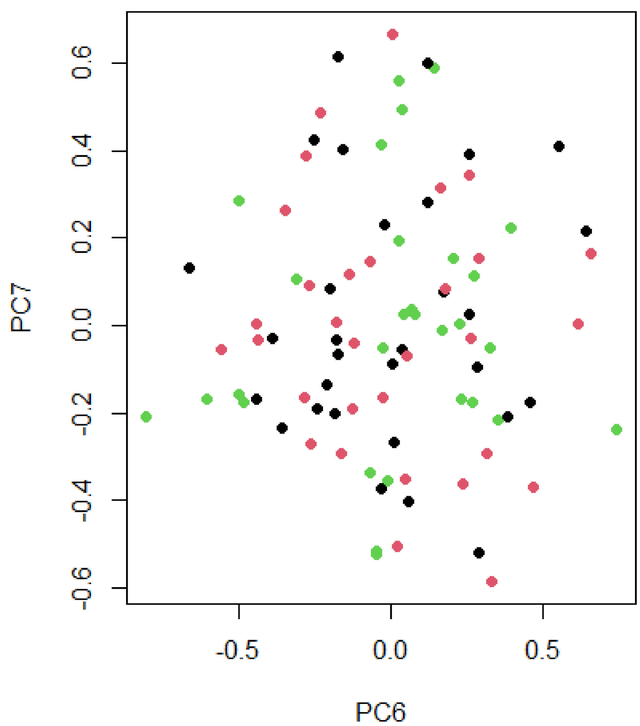


Figure 1. (**a**) K−Means Clustering Algorithm to growth performances of juvenile *L. vannamei* shrimps fed with mixture 1; (**b**) K−Means Clustering Algorithm to growth performances of juvenile *L. vannamei* shrimps fed with the mixture 2.

The size of each cluster has relation with the number of data points, the graphic (a): size of Cluster 1 (color red) is 28, the size of Cluster 2 (color black) is 32, and the size of Cluster 3 (color green) is 30. Juvenile *L. vannamei* shrimps fed with the mixture M1 belonging to Cluster 2 showed the highest values of growth performances. Otherwise, the graphic (b): size of Cluster 1 (color black) is 30, the size of Cluster 2 (color green) is 29, and the size of Cluster 3 (color red) is 31. Juvenile *L. vannamei* shrimps fed with the mixture M2 belonging to Cluster 3 showed the highest values of growth performances. Since the data points are normally distributed, clusters vary in size with maximum data points and minimum data points.

The aquaculture binder can be used to mix with other ingredients such as: antibiotics, vitamins, and organic acids to control bacterial infections and improve shrimp reproductive performance and egg hatching rate [31]. There is no beneficial effect of increasing the feeding frequency or ration size on the growth or survival of shrimp (*L. vannamei*) [32].

Figure 2 shows the factorial graph of the plane 1–2 (PCA-Biplot); graphic (a) presents the accumulated inertia amounts to 49.1%, while graphic (b) presents the accumulated inertia amounts to 47%.

(a)

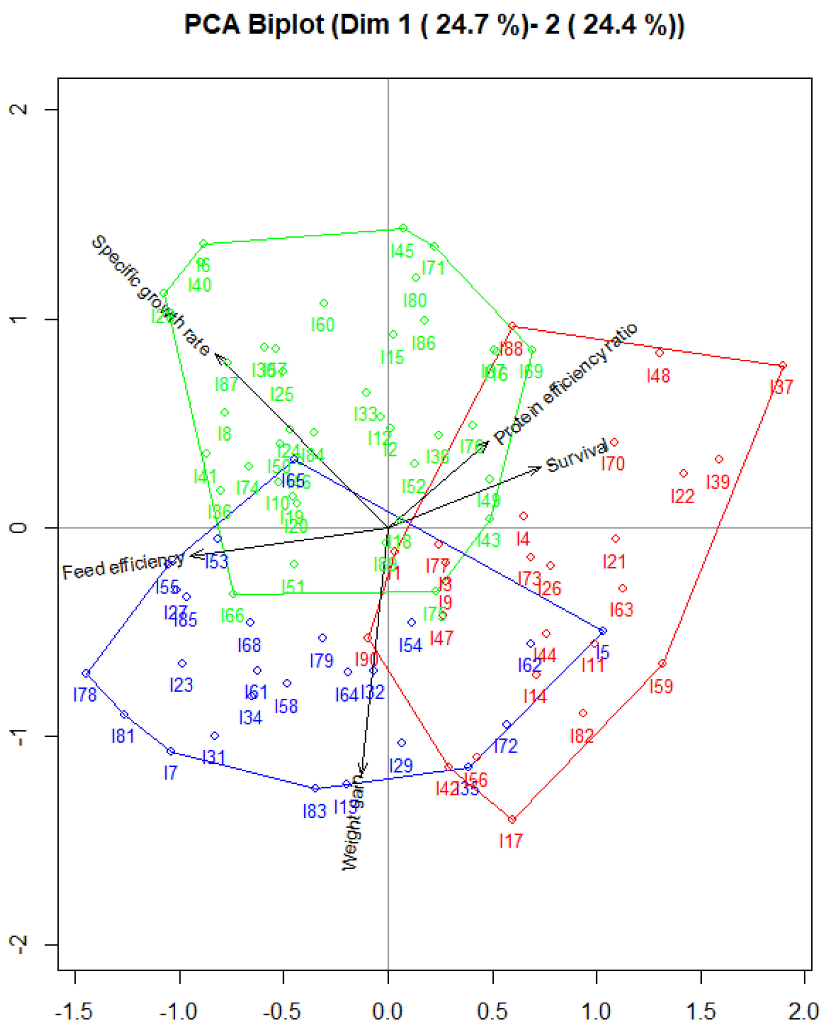


Figure 2. *Cont.*

(**b**)

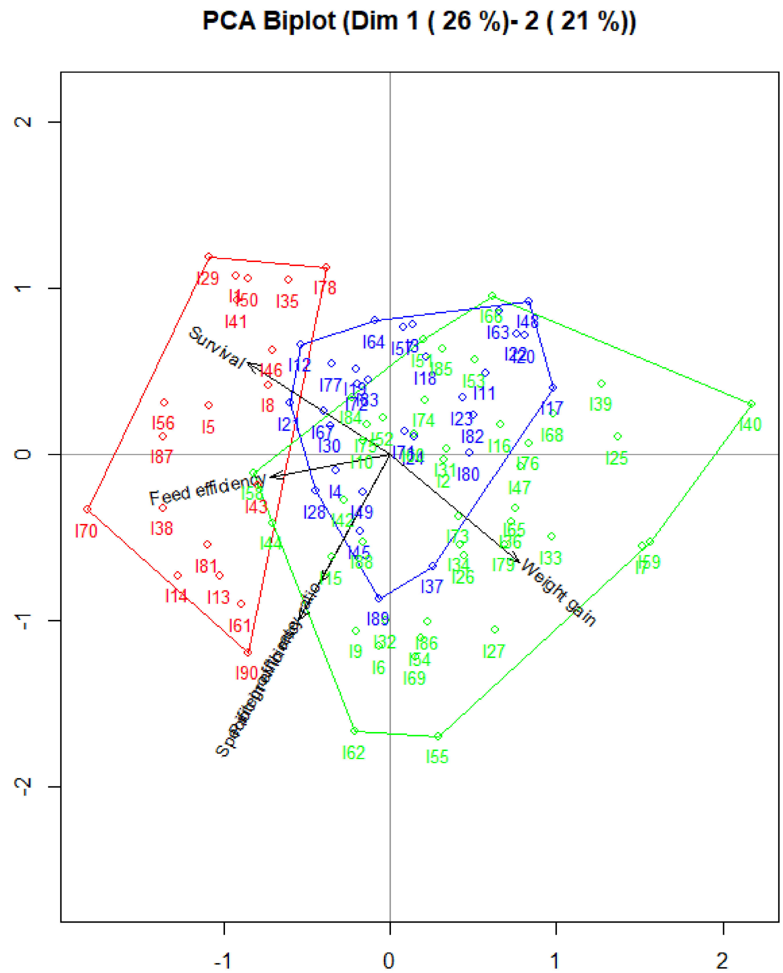


Figure 2. (**a**) PCA Biplot to growth performances of juvenile *L. vannamei* shrimps fed with the mixture 1; (**b**) PCA Biplot to growth performances of juvenile *L. vannamei* shrimps fed with the mixture 2.

In addition, clusters have been calculated using the Biplot coordinates; the overview of clusters is based on five variables. We observe in graphic (a) important differences between clusters. Cluster 1 (color blue) indicates the presence of 25 juvenile *L. vannamei* shrimps fed with the mixture M1 with higher relation to feed efficiency and weight gain, while Cluster 2 (color green) indicates the presence of 40 juvenile *L. vannamei* shrimps fed with the mixture M1 with higher relation to specific growth rate and protein efficiency ratio, and Cluster 3 (color red) indicates the presence of 25 juvenile *L. vannamei* shrimps fed with the mixture M1 with higher relation to specific survival.

Otherwise, in graphic (b) there are also differences between the clusters. Cluster 1 (color red) indicates the presence of 19 juvenile *L. vannamei* shrimps fed with the mixture M2 with higher relation to feed efficiency, whereas Cluster 2 (color blue) indicates the presence of 30 juvenile *L. vannamei* shrimps fed with the mixture M2 with higher relation to all the parameters, and Cluster 3 (color green) indicates the presence of 41 juvenile *L. vannamei* shrimps fed with the mixture M2 with higher relation to specific growth rate, weight gain, and protein efficiency ratio.

Diets that contained more fish meal produced the best growth, survival, and protein efficiency, which can be attributed to the desirable parameters for the feed shrimp above, which are high digestibility and attractiveness as well as a balanced amino acid profile [33]. The shrimp fed during the day grew as well as, and had better feed efficiency and survival than, those fed at night [34]. Protein efficiency ratio values are related with the protein level, and this is attributed to the use of protein excess as an energy source instead of mass formation [35]. The use of binders with sardine in diets can improve the growth performances due to increasing the feeding and less food waste.

3.2. Data Mining for Nutritional Composition of Juvenile Shrimps

Figure 3 presents the application of method K-means clustering algorithm to 90 objects having 5 variables, each one using the software RStudio. Graphic (a) presented the use of three clusters for nutritional composition of juvenile *L. vannamei* shrimps fed with mixture 1, while in graphic (b) the use of three clusters for nutritional composition of juvenile *L. vannamei* shrimps fed with mixture 2 was also shown. The results show the normal distribution of 90 data points around three clusters in each graphic.

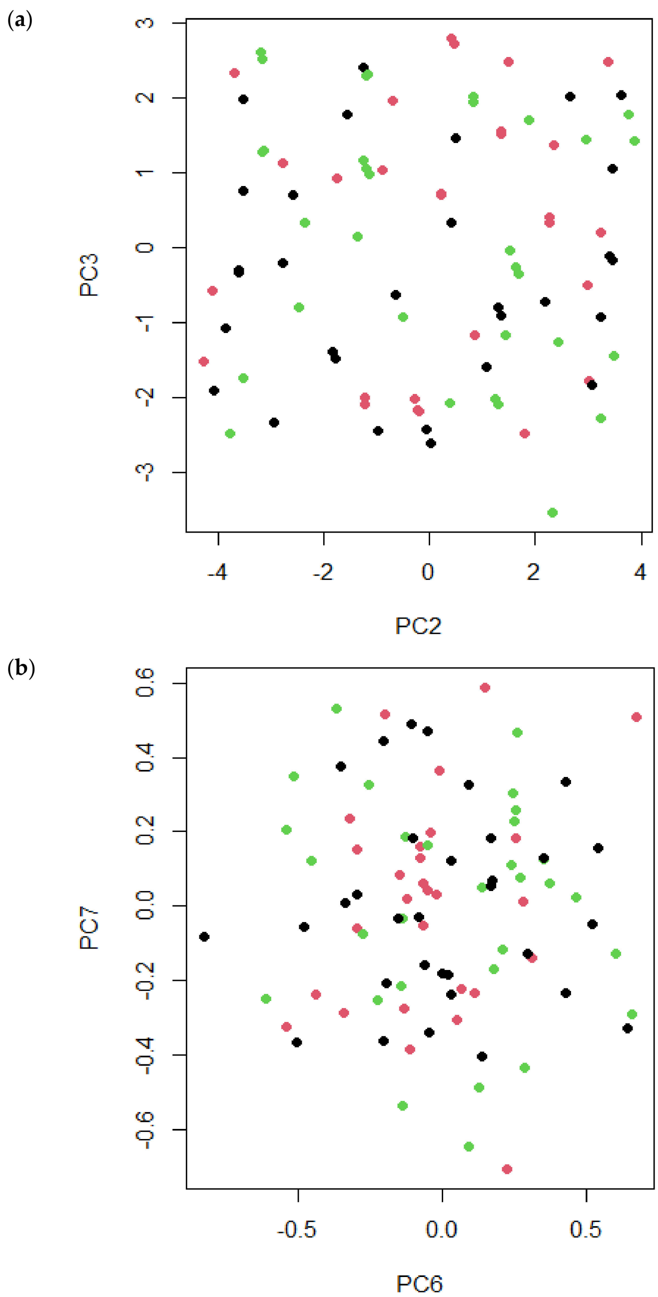


Figure 3. (**a**) K−Means Clustering Algorithm for nutritional composition of juvenile *L. vannamei* shrimps fed with mixture 1; (**b**) K−Means Clustering Algorithm for nutritional composition of juvenile *L. vannamei* shrimps fed with mixture 2.

The size of each cluster is in relation to the number of data points, graphic (a): size of Cluster 1 (color red) is 31, the size of Cluster 2 (color black) is 30, and the size of Cluster 3 (color green) is 29. Juvenile *L. vannamei* shrimps fed with mixture M1 belonging to Cluster 1 showed the highest values of nutritional parameters. Otherwise, in graphic (b): the size of Cluster 1 (color black) is 30, the size of Cluster 2 (color green) is 28, and the size of Cluster 3 (color red) is 32. Juvenile *L. vannamei* shrimps fed with mixture M2 belonging to Cluster 3 showed the highest values of nutritional parameters. Since the data points are normally distributed, clusters vary in size with maximum data points and minimum data points.

Figure 4 presents the factorial graph of the plane 1–2 (PCA-Biplot); graphic (a) presents the accumulated inertia amounts to 56%, while graphic (b) presents the accumulated inertia amounts to 54.1% In addition, clusters have been calculated using the Biplot coordinates; the overview of clusters is based on four variables.

We observe, in graphic (a), important differences between clusters. Cluster 1 (color green) indicates the presence of 35 juvenile *L. vannamei* shrimps fed with mixture M1 with higher relation of moisture and crude lipid, while Cluster 2 (color red) indicates the presence of 36 juvenile *L. vannamei* shrimps fed with mixture M1 with higher relation to ash, and Cluster 3 (color blue) indicates the presence of 19 juvenile *L. vannamei* shrimps fed with mixture M1 with higher relation to crude protein. On the other hand, in graphic (b) there are also differences between the clusters. Cluster 1 (color green) indicates the presence of 23 juvenile *L. vannamei* shrimps fed with mixture M2 with higher relation to crude protein and crude lipid, whereas Cluster 2 (color blue) indicates the presence of 30 juvenile *L. vannamei* shrimps fed with mixture M2 with higher relation to ash, and Cluster 3 (color red) indicates the presence of 37 juvenile *L. vannamei* shrimps fed with mixture M2 with higher relation to ash and moisture.

(**a**)

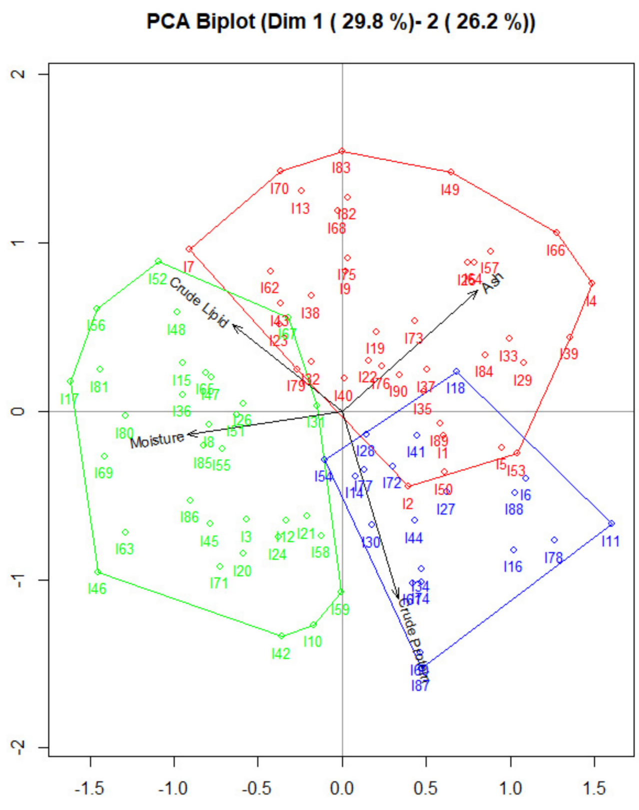


Figure 4. *Cont.*

(**b**)

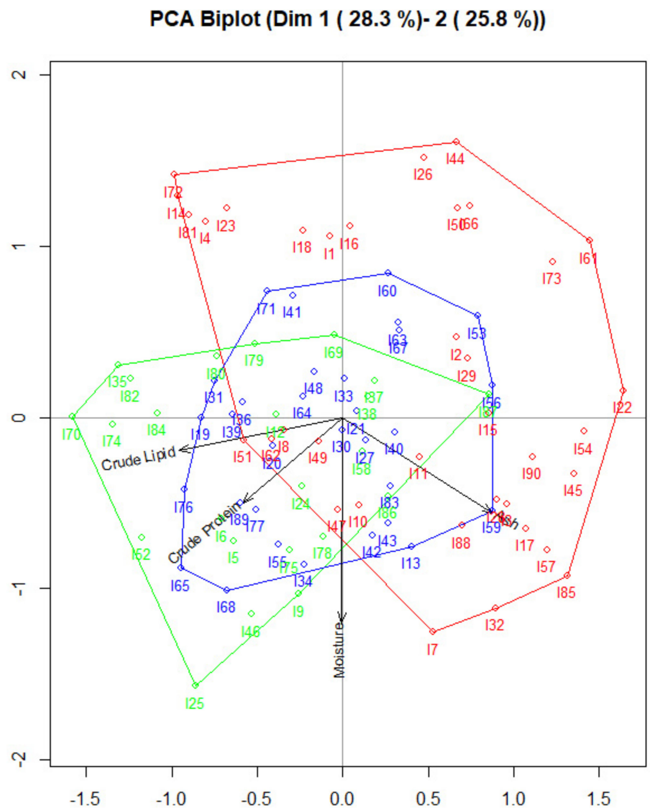


Figure 4. (**a**) PCA Biplot for nutritional composition of juvenile *L. vannamei* shrimps fed with mixture 1; (**b**) PCA Biplot for nutritional composition of juvenile *L. vannamei* shrimps fed with mixture 2.

The nutrient composition of shrimp is affected by shrimp species and breeding region [36]. A good protein source for animal nutrition purposes is that with a balanced content of amino acids [37]. The high crude protein in seafood consists of 70–80% myogenic fibronectin and 20–30% sarcoplasmic protein. The ash content reflects the content of inorganic compounds in biological samples, to a certain extent [38]. In relation to the crude lipid, the hepatopancreas is the storehouse of lipids, including triglycerides and phospholipids [39]. Shrimp and shrimp subproducts are the most consumed types of seafood because of their nutritional value [40]. The highest values of nutritional composition in the shrimps' bodies obtained with these diets can help to improve the aquaculture in small scale shrimp farmers.

The PCA Biplot depends on data preprocessing and variable selection and also uses singular value decomposition (SVD) of the data matrix [41], while the K-means algorithm assigns each object to the group that has the nearest centroid [42]. The results indicate that the data mining can describe a good visualization of the conditions of feeding with the objective to obtain specific commercial parameters of juvenile *Litopenaeus vannamei* shrimps, such as growth performance or nutritional composition.

4. Conclusions

Data mining tools such as PCA Biplot and K-means algorithm presented that juvenile *Litopenaeus vannamei* shrimps fed with mixture 2 presented the highest relation with specific growth rate, weight gain, protein efficiency ratio, crude protein, and crude lipid.

The use of data mining techniques on commercial parameters of juvenile *Litopenaeus vannamei* shrimps allows the conditions of feeding to be determined in order to obtain the highest values in specific parameters such as growth performance or nutritional composition.

The use of a binder with sardine allows a higher consumption of pellets to be obtained; a similar result was presented in other studies that used a mixture of pellet with a tuna binder, and the consumption was higher in comparison with only pellets.

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