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Canonical Correlation Analysis on Physicochemical Data and Proximate Data in the Case of Goat Milk Yoghurt Mixed with *Basella* spp. Fruit Powder

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Abstract

This study aims to examine the relationships between two datasets of an experiment on goat milk yoghurt mixed with *Basella* spp. fruit powder. We use canonical correlation in investigating the relationships between physicochemical variables: pH, lactic acid, viscosity, L* color, a* color, b* color and proximate variables: protein, fat, ash, fibre, humidity, carbohydrate. Our results are obvious that some variables of two data have high canonical correlations, that is, {viscosity, L* color, a* color, b* color} and {fibre, humidity, carbohydrate}, which are used for constructing canonical variates. We obtain that the first canonical variates explain the proportion of variability of about 67.43% with high canonical correlation 0.902, whereas the second and third canonical variates explain the proportion of variability of about 21.52% and 11.05%, respectively. Consequently, a squared canonical correlation of the first canonical variates is high (0.8136), that is, 81.36% of the variation in the first physicochemical canonical variable is explained by the variation in the first proximate canonical variable. These results are very useful for designing our next experiment in reducing the complexity of data collection and extravagant expense. We can also develop nutrition of our yoghurt in the future.

Keywords: Canonical correlation, physicochemical data, proximate data, Wilks' lambda, canonical variate.

1. Introduction

Hotelling (1935, 1936) discovered canonical correlation, which is a method for figuring out how two sets of variables are related to one another. Simple and multiple correlation are specific examples of canonical correlation. Canonical correlation analysis takes two sets of data and selects a linear combination from each set that maximizes the correlation between two canonical variables. This linear combination is referred to as a canonical variable. The best overall measure of association is the largest squared canonical correlation, that is, the first canonical correlation is the maximum correlation between linear functions of two sets of variables. Any variable and the opposite set of variables have many multiple correlations that are at least as large as the first canonical correlation. All numerous correlations may be negligible when predicting one of the original variables from the opposing set of canonical variables, but the first canonical correlation may be highly significant. The next phase in the canonical correlation analysis is to find a second set of canonical variables that have the second-highest correlation coefficient and are uncorrelated with the first pair. The procedure of generating canonical variables is repeated until the number of canonical variable pairs is equal to the number of variables in the smaller group.

In many years, researchers of various study fields have used canonical correlation analysis in their numerous studies, since it is a highly helpful tool for examining correlations between groups of variables. For instance, Akbas and Takma (2005) estimated the relationships between age at sexual maturity, egg weight, and body weight utilizing layer data and canonical correlation analysis. The age at sexual maturity was shown to be the most significant contributor to the variance in the number of eggs produced at three different periods, as indicated by the canonical weights and loadings from the canonical correlation analysis, when compared to body weight and egg weight. Cai et al. (2014) used canonical correlation analysis to examine the integrated linear correlation between the physicochemical characteristics and the dielectric properties of Fuji apples. An integrated linear correlation value of 0.793 in the experimental results suggests a strong relationship between the physicochemical and dielectric characteristics of apples. Tipkanjanarat and Wasusri (2015) investigated the relationship between factors influencing raw water quality and chemical consumption using canonical correlation techniques. Understanding incoming water quality, or “raw water,” is crucial to effectively treating water. The quality of raw water is influenced by fourteen factors, such as turbidity, color, volume, and iron concentration. These 14 factors have an impact on how many chemicals are used to treat raw water. The chemical components include H_2O_2, polymer, lime, alum, chlorine, and activated carbon. There is a relationship between these two variables, as indicated by the correlation coefficient of 0.9489. Iweka et al. (2018) discussed the use of canonical correlation analysis in necessity of multivariant analysis in educational research. They obtained the result of a good correlation between the outcomes of aptitude test scores and standardized test scores. Mussina and Bachisse (2018) jointly explored the two main pillars of national competitiveness, “Business Sophistication” and “Macroeconomic Environment,” none of which had previously been adequately examined. Canonical correlation analysis has been employed in the study to investigate the interaction between the two pillars. The results of their study showed a significant and positive relationship between the variables “Business Sophistication” and “Macroeconomic Environment”. Que et al. (2020) used canonical correlation to study the relationship between shipping development and the water environment of the Yangtze River. The results showed a clear connection between Yangtze River shipping and river water quality. Furthermore, the amount of wastewater discharged into the river and the level of petroleum pollution in the water are significantly impacted by the volume of mainline freight. Nouri et al. (2022) conducted a study to determine the impact of information and communication technology (ICT) usage and access on academic motivation and accomplishment. According to canonical correlation analysis, ICT-related characteristics and academic achievement are significantly correlated. The most important element influencing academic success was pupils' use and access to ICT at school. The most crucial factors linked to academic motivation also included having access to ICT at school and utilizing digital gadgets at a younger age. Nayir and Saridas (2022) used canonical correlation analysis based on instructor perceptions to ascertain the relationship between culturally responsive teacher roles and innovative work behavior according to teachers’ views. The first canonical function, which is computed to optimize the link between the two, has a variance of around 77% that is shared by creative work behavior data sets and culturally sensitive teaching roles. Vargas (2023) used canonical correlation analysis to investigate the multivariate link between linoleic acid, alpha-linolenic acid, and their main rumen biohydrogenation intermediates and products in bovine rumen fluid. Akour et al. (2023) used the canonical correlation test to determine the strength of the relationship between the levels of face-to-face education and online business students at Al-Balqa Applied University. They did this by identifying the linear combinations of the two sets of variables with the highest correlation. The first, second, and third outcomes of the investigation were obtained. Kilinc (2023) used canonical correlation analysis to investigate the connection between psychological resilience and attachment styles. Three canonical functions about the connection between psychological resilience and attachment patterns were derived from the canonical correlation analysis. It was determined that there was statistical significance in the correlation values obtained for the first and second canonical functions. Schoffel et al. (2023) used canonical correlation analysis to ascertain the associations between the traits of the cassava stem cutting, seedling, stem, and root groups. Associations between the groups stem cutting and seedling were established by weighing and measuring the stem cuttings as well as the height and number of leaves after planting. They found that the characteristics of the seedlings had the greatest impact on the number of buds per stem and stem diameter. Based on the main stem branching height and stem diameter, plants may be selected that have the best quality and yield of root characteristics

It is clearly seen that canonical correlation is a very useful technique for investigating the relationship between two sets of data in various fields of study. Thus, our research objective is to use canonical correlation analysis in investigating the relationships between physicochemical data and proximate data that we obtained from our experiment, such that we have 6 variables of physicochemical data, that is, pH, lactic acid, viscosity, L* color (lightness), a* color (redness), b* color (yellowness) and 6 variables of proximate data, i.e., protein, fat, ash, fibre, humidity, carbohydrate. For improving our experimental design in our next experiment, we must investigate the two sets of variables of both physicochemical data and proximate data to find the groups of data that have high correlations in order to maintain them in our next experiment, for reducing the complexity of data collection in our laboratory and unnecessary expenses. Furthermore, we can use the consequent analytic results in developing nutrition of our goat milk yoghurt (mixed with *Basella* spp. fruit powder) in the future

In the first step of consideration, pairwise scatter plots can be made using the variables from the first data and the variables from the second data as shown in the next section. However, there will be pq scatter plots if the first set's dimensions are p and the second set's dimensions are q. Understanding the data by looking at all of these graphs at once would be challenging, if not impossible. Furthermore, we could also compute all correlations between the variables in the first data and the variables in the second data in a similar way, although interpretation gets difficult when pq is high. That is our reason we use canonical correlation analysis which is a dimension-reduction technique to reduce numbers of variables for designing in the next experimental plan, which is very essential.

The structure of this paper is designed to provide a comprehensive understanding of canonical correlation. Section 2 presents methodology and discussion, followed by Section 3 presents conclusions that demonstrates the results by canonical correlation technique in analyzing our two sets of variables.

2. Methodology and Discussion

In this study, the used materials are commercial yoghurt containing Lactobacillus delbrueckii subsp. bulgaricus and Streptococcus thermophilus, and raw goat milk from goats on a farm in the Chachoengsao Province of Thailand. Furthermore, we mixed the goat milk yoghurt with *Basella* spp.

fruit powder. During storage for 21 days at 4±1°C, physicochemical properties were analyzed, that is, we measured the observed values of all variables with eighteen sample units, and then we had physicochemical data consisting of the observed values of 6 variables: pH, lactic acid, viscosity, L* color (lightness), a* color (redness), b* color (yellowness). Furthermore, we obtained proximate data consisting of observed values of 6 variables: protein, fat, ash, fibre, humidity, carbohydrate that were measured at Laboratory of Faculty of Science and Technology, Rajamangala University of Technology Tawan-ok, Thailand (Sansawat et al. 2022).

Our study objective is to explore the relationships between physicochemical data and proximate data which are defined by data $\mathbf{X}$ and $\mathbf{Y}$, respectively. The canonical correlation technique provided a detailed explanation of the relationship between these two data. We do not necessarily think of one of two data containing independent variables and the other containing dependent variables, however, there may be an alternative viewpoint. We are able to condense the connections into fewer data while keeping the important aspects of the associations by employing canonical correlation analysis, which is a method of reducing dimensions, similarly principal component analysis

For our study, we have two data of variables, $\mathbf{X}$ and $\mathbf{Y}$. We define number of variables in physicochemical data as p, that is, $p=6$, and we define number of variables in proximate data as q, that is we have $q=6$, as the following details.

$\mathbf{X}=\left(X_1,X_2,...,X_p\right)=\left(X_1,X_2,...,X_6\right)$ defined by $X_1=$ pH, $X_2=$ lactic acid, $X_3=$ viscosity, X_4 = L* color (lightness), $X_5=$ a* color (redness) and $X_6=$ b* color (yellowness)

$\mathbf{Y}=\left(Y_1,Y_2,...,Y_q\right)=\left(Y_1,Y_2,...,Y_6\right)$ defined by $Y=$ protein, $Y_2=$ fat, $Y_3=$ ash, $Y_4=$ fibre, $Y_5=$ humidity and $Y_6=$ carbohydrate

In the next step of consideration, we considered a collection of linear combinations. The linear combination from $\mathbf{X}$ is called U, whereas the linear combination from $\mathbf{Y}$ is called V.

(U_i,V_i) is called the i^{th} canonical variate pair, (U_1,V_1) is the first canonical variate pair, such that the linear functions U_1 and V_1 are called the first canonical variates. That is, (U_2,V_2) is the second canonical variate pair, and so on. It is obvious that there are p canonical covariate pairs with $p\le q$, corresponding to canonical correlations $r_1,r_2,...,r_s$ where $s=\min(p,q)$.

In the case of $p=6$, we obtain

$$\begin{aligned}U_1&=a_{11}x_1+a_{12}x_2+\cdots+a_{16}x_6\\U_2&=a_{21}x_1+a_{22}x_2+\cdots+a_{26}x_6\\&\vdots\\U_6&=a_{61}x_1+a_{62}x_2+\cdots+a_{66}x_6.\end{aligned}$$

Similarly, in the case of $q=6$, we obtain

$$\begin{aligned}V_1&=b_{11}y_1+b_{12}y_2+\cdots+b_{16}y_6\\V_2&=b_{21}y_1+b_{22}y_2+\cdots+b_{26}y_6\\&\vdots\\V_6&=b_{61}y_1+b_{62}y_2+\cdots+b_{66}y_6.\end{aligned}$$

Note that $U = \mathbf{a}'\mathbf{X}$ and $V = \mathbf{b}'\mathbf{Y}$. We define covariance matrices of **X**, **Y** and between **X** and **Y** as $\Sigma_{\mathbf{X}}$, $\Sigma_{\mathbf{Y}}$ and $\Sigma_{\mathbf{XY}}$, respectively. We obtain $Var(U) = \mathbf{a}'\Sigma_{\mathbf{X}}\,\mathbf{a}$, $Var(Y) = \mathbf{b}'\Sigma_{\mathbf{Y}}\,\mathbf{b}$ and $Cov(U,V) = \mathbf{a}'\Sigma_{\mathbf{XY}}\,\mathbf{b}$.

From these above equations, we wish to find linear combinations that maximize the correlations between the members of each canonical variate pair or the correlation between U_i and V_i, $i = 1, 2, ..., s$ where $s = \min(p, q)$. Since we have $p = 6$ and $q = 6$, thus we have $s = 6$. That is, we have 6 canonical correlations corresponding to the 6 pairs of canonical variates U_i and V_i, computed by

$$\frac{Cov(U_i, V_i)}{\sqrt{Var(U_i)Var(V_i)}}.$$

The coefficients $a_{11}, a_{12}, \cdots, a_{1p}$ and $b_{11}, b_{12}, \cdots, b_{1q}$ are selected to maximize the canonical correlation to find the first canonical variate pair (U_1, V_1).

For our data of 6 physicochemical variables and 6 proximate variables, we obtain the correlations of the two sets of variables and pairwise scatter plots. There are both high and low correlations for each pair of variables.

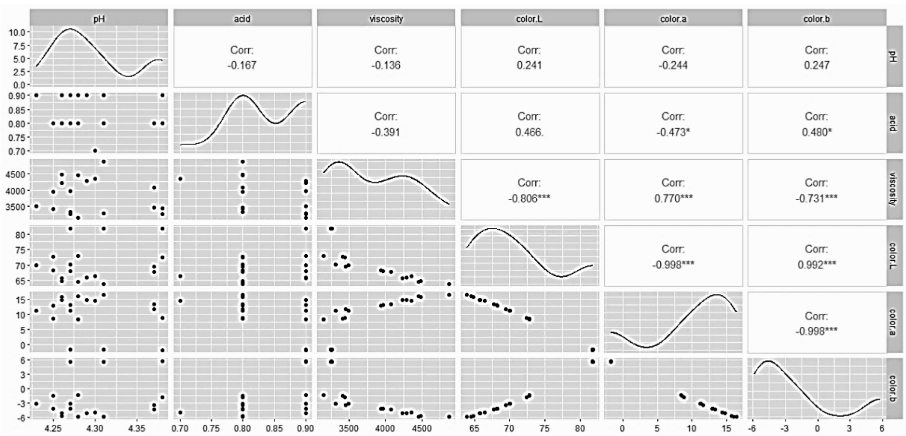

Figure 1. Correlation matrices and pairwise scatter plots for all variables of physicochemical data and proximate data

To evaluate the independence between the variables of the two sets of data, we first assess a multivariate multiple regression model in which we predict the variables of the proximate data from the variables of the physicochemical data. We wish to test the null hypothesis, which claims that all of these regression coefficients equal zero, with the exception of the intercepts. This would be the same as the null hypothesis, which holds that the first set of variables is independent of the second set of variables. To achieve this, Wilks' lambda test is used, such that a ratio of two variance-covariance matrices is called the Wilks' lambda. The idea that there is no correlation between the two sets of variables is known as the null hypothesis, and we reject the null hypothesis if these statistics show big values (small p-values). From using our data with all variables, we accepted the null hypothesis with the results of Wilks' lambda test, as shown in the following output.

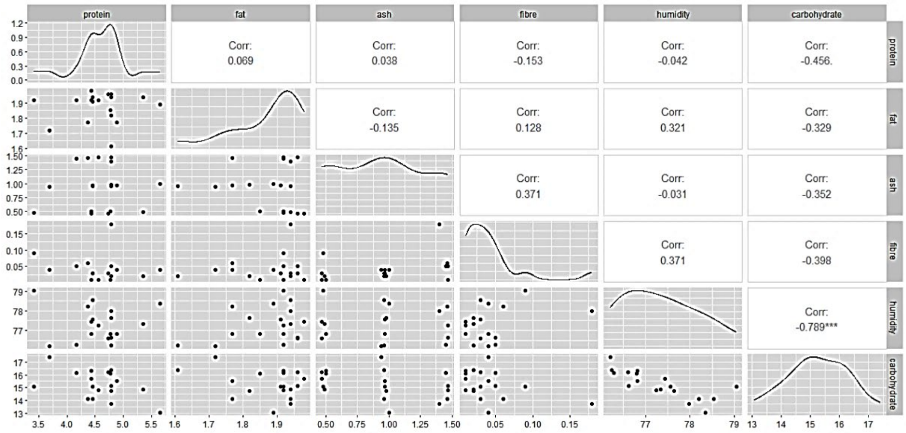

Figure 1. (Continued)

Table 1. The results of Wilks' lambda test

Lambda	F	df1	df2	Pr>F
0.023	1.106	36	29.109	0.394
0.237	0.521	25	27.506	0.948
0.515	0.381	16	25.078	0.976
0.702	0.383	9	22.054	0.931
0.882	0.325	4	20.000	0.858
1.000	0.000	1	11.000	0.994

In our results in Table 1, there is no relationship between the two sets of variables, that is, we conclude that the set of 6 variables of physicochemical data and the set of 6 variables of proximate data are independent, corresponds to the obtained correlation matrix of all variables of both data that have low correlation values in some pairs of variables, shown in Table 2. Thus, we should select the variables with high correlation values to continue studying, which corresponds to this idea of multivariate data analysis.

Table 2. Correlation matrix of all variables of both data

Variables	protein	fat	ash	fibre	humidity	carbohydrate
pH	0.156	0.292	-0.104	0.194	0.292	-0.298
acid	0.054	0.417	-0.063	0.043	0.425	-0.374
viscosity	-0.197	-0.340	0.020	0.009	-0.708	0.668
color L	0.015	0.247	-0.099	0.114	0.845	-0.656
color a	0.005	-0.244	0.115	-0.111	-0.840	0.636
color b	-0.028	0.233	-0.120	0.117	0.831	-0.616

Essentially, a researcher can use canonical correlations with the remaining of more significant variables. From our previous correlation matrix, we have chosen some variables from both data to investigate the relationship of the selected variables by using canonical correlation analysis. The selected variables of physicochemical data are consisting of viscosity, L* color, a* color, b* color, and the selected variables of proximate data are consisting of fibre, humidity, carbohydrate with their correlations shown in Figure 2. After applying canonical correlation analysis to a chosen set of variables, it seems to be significantly related.

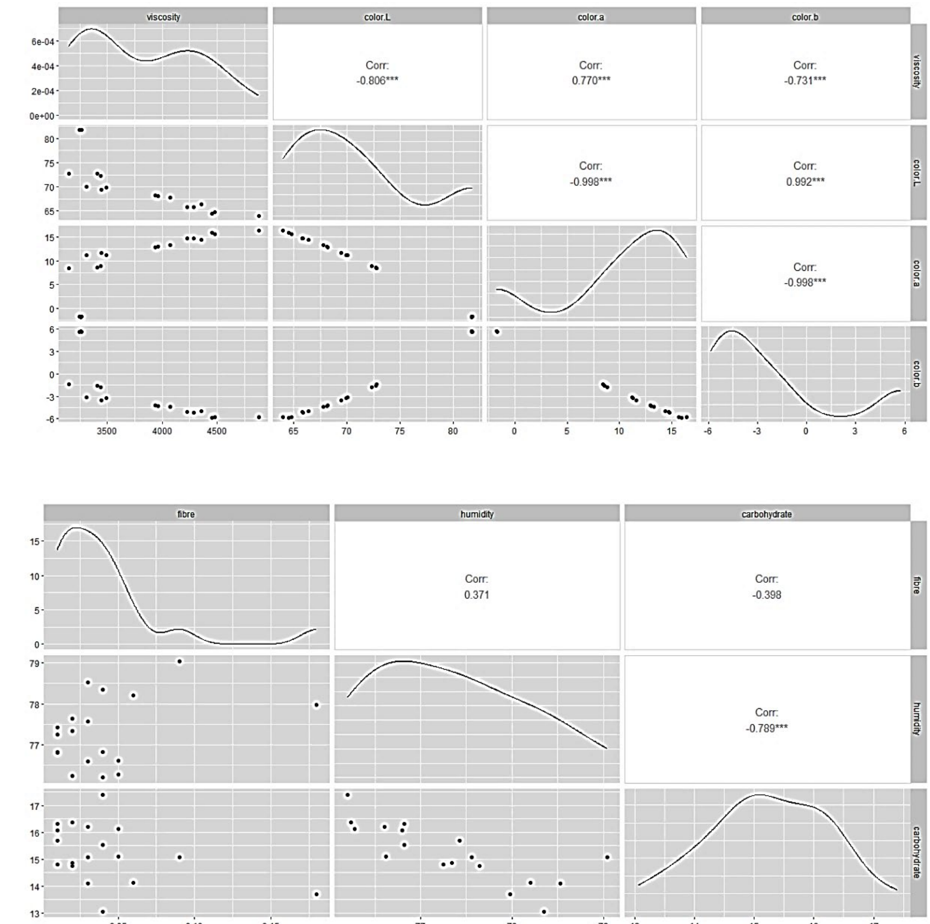

Figure 2. Correlation matrices and pairwise scatter plots for the selected variables of physicochemical data and proximate data

These selected variables of both data yield Wilks' lambda test, as follows:

Table 3. The results of Wilks' lambda test for the selected variables

Lambda	F	df1	df2	Pr>F
0.1224	2.9697	12	29.395	0.00795
0.6470	0.9728	6	24.000	0.46463
0.8687	0.9823	2	13.000	0.40061

Wilks' lambda test allows to test whether the canonical variables are linked to the initial data or not. From the first line of Table 3, we obtained Wilks' lambda $\Lambda = 0.1224$, $F = 2.9697$, p-value < 0.05, such that Wilks' lambda is significant, so we rejected the null hypothesis, that is, the two sets of selected variables are dependent, especially Factor 1 is significant, but Factor 2 and Factor 3 are poorly related to the initial data with canonical correlations that ordered from largest to smallest as follows:

	Factor 1	Factor 2	Factor 3
canonical correlation	0.902	0.510	0.365
	Factor 1	Factor 2	Factor 3
squared canonical correlation	0.8136	0.2601	0.1332

We also considered the squared canonical correlations. We have seen that 81.36% of the variation in U_1 is explained by the variation in V_1, but 26.01% of the variation in U_2 is explained by V_2, and only 13.32% of the variation in U_3 is explained by V_3, corresponds to our scree plots of data.

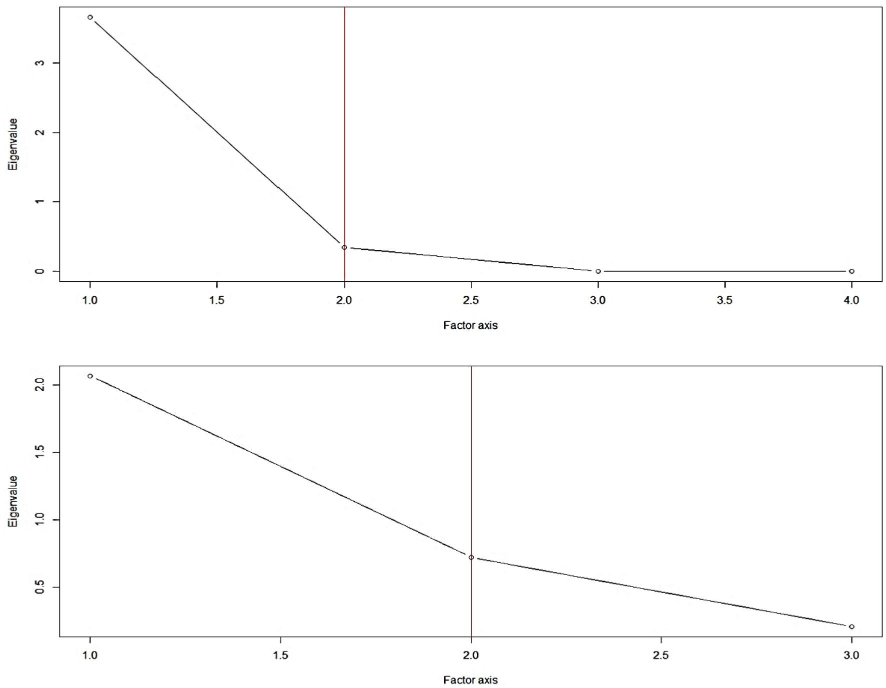

Figure 3. Scree plots for the selected variables of physicochemical data and proximate data

The results in Table 4 yield an explanation that the first factor alone explains 67.43% of the variability, the second factor explains 21.52% of the variability, and the third factor explains 11.05% of the variability.

Table 4. Variability values

	Factor 1	Factor 2	Factor 3
eigenvalue	0.8136	0.2601	0.1332
variability (%)	67.43	21.52	11.05
cumulative (%)	67.43	88.95	100.00

Finally, we obtained the standardized canonical coefficients for physicochemical data and proximate data as follows:

Table 5. Standardized canonical coefficients for physicochemical variables

	Factor 1	Factor 2	Factor 3
viscosity	–0.31	–1.78	0.06
color L*	–9.99	–38.00	–19.84
color a*	–21.24	–63.18	–26.38
color b*	–10.59	–26.98	–6.44

Using the coefficient values in the first column of Factor 1, the first canonical variable for physicochemical variables is determined using the following formula:

$$U_1 = \text{-0.31 viscosity -9.99 color L* -21.24 color a* -10.59 color b*}$$

Table 6. Standardized canonical coefficients for proximate variables

	Factor 1	Factor 2	Factor 3
fibre	–0.45	–1.00	–0.09
humidity	0.97	–0.35	1.27
carbohydrate	–0.14	–0.40	1.60

Using the coefficient values in the first column of Factor 1, the first canonical variable for proximate variables is determined using the following formula:

$$V_1 = -0.45 \text{ fibre} + 0.97 \text{ humidity} - 0.14 \text{ carbohydrate.}$$

The magnitudes of the coefficients in both cases indicate the contributions of each individual variable to the related canonical variates. Linear functions U_1 and V_1, the first canonical variates with canonical correlation 0.902, explain the proportion of variability of about 67.43%, whereas the second canonical variates with canonical correlation 0.510, explain the proportion of variability of about 21.52%, and the third canonical variates with canonical correlation 0.365, explain 11.05% of the variability. It has been obvious that physicochemical variables {viscosity, color L*, color a*, color b*} and proximate variables {fibre, humidity, carbohydrate} were used for linear functions U_1 and V_1 which could explain 67.43% of the variability with high canonical correlation. Those canonical correlation results correspond to the multiple correlation that we tried to investigate also. We obtained high multiple correlations for each dependent variable {fibre, humidity, carbohydrate} with the same set of independent variables {viscosity, color L*, color a*, color b*}, as shown in Table 7.

Table 7. Multiple correlations for each dependent variable with the same set of independent variables

A set of independent variables	Each dependent variable	Multiple correlation
viscosity color L* color a* color b*	protein	0.4021
	fat	0.4772
	ash	0.4817
	fibre	0.5024
	humidity	0.8488
	carbohydrate	0.7083

3. Conclusions

From our results of the study, we have seen that there are some variables with high correlations between two sets of physicochemical data and proximate data, that is, a set of physicochemical variables {viscosity, color L*, color a*, color b*} and another set of proximate variables {fibre, humidity, carbohydrate}. These two sets of variables are used to construct the linear functions U_1 and V_1 (the first canonical variates) with high canonical correlation 0.902, which explains 67.43% proportion of variability, while the second and third canonical variates yield less proportions of variability, respectively. Since the first canonical variates have high canonical correlation 0.902, it causes a squared canonical correlation of the first canonical variates at a high value (0.8136), that is, it is shown that 81.36% of the variation in the first physicochemical canonical variable is explained by the variation in the first proximate canonical variable. This result is important for designing our next experiment in reducing the complexity of data collection and wasteful spending. In addition, we can develop nutrition of our goat milk yoghurt (mixed with *Basella* spp. fruit powder) in the future. The obtained results of canonical correlation are similar to the results of multiple correlation method. It is better to analyze the relationships of two sets of variables by canonical correlation even if sizes of the experimental units are large or small because we can obtain or know the studied variables that have high correlations in both cases of within and between sets of variables, whereas multiple correlation cannot do that because the multiple correlation method yields the correlations for each dependent variable. It is obvious that canonical correlation is a very useful technique for our study in considering the relationships of two data, physicochemical data and proximate data, that is, it is a useful and efficient way to look at the relationships between two sets of variables (assuming several dependent and independent variables). The outcomes of a canonical analysis can address the number of connections, strength, and kind of links between the two sets of multiple variables.

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References

Akbas Y, Takma C. Canonical correlation analysis for studying the relationship between egg production traits and body weight, egg weight and age at sexual maturity in layers. Czech J Anim Sci. 2005; 50(4): 163-168.

Akour I, Alrahamneh A, Kurdi B, Alhamad A, Almakhareez LS, Alshurideh MT, Alhawary S. Using the canonical correlation analysis method to study students' levels in face-to-face and online education in Jordan. Int J Inf Sci Lett. 2023; 12(2): 901-910.

Cai C, Li Y, Wang S, Ma H. Canonical analysis to dielectric features and physicochemical features of Fuji apple. 2014 [cited 2024 April 29]. Available from: www.apsipa.org/proceedings/2014/Data/paper/1144.pdf

Hotelling H. The most predictable criterion. J Educ Psychol. 1935; 26: 139-142.

Hotelling H. Relations between two sets of variates. Biometrika. 1936; 28(3-4): 321-377.

Iweka, Fedelis, and Anthonia MA. Canonical correlation analysis, a sine quanon for multivariant analysis in educational research. Int J Humanit Soc Sci Educ. 2018; 5(7): 116-126.

Kilinc E. Examining the relationship between adolescents' psychological resilience and attachment styles using canonical correlation. Int J Psychol Educ Stud. 2023; 10(2): 441-452.

Mussina KP, Bachisse M. Canonical correlation analysis between business sophistication and macroeconomic environment: A secondary study of countries global competitiveness. Espacios. 2018; 39(18): 32-41.

Nayir F, Saridas G. The relationship between culturally responsive teacher roles and innovative work behavior: Canonical correlation analysis. JERAP. 2022; 12(1): 36-50.

Nouri A, Zandi T, Etemadizade H. A canonical correlation analysis of the influence of access to and use of ICT on secondary school students' academic performance. Res Learn Technol. 2022; 30: 2679, doi:10.25304/rlt.v30.2679.

Que S, Luo H, Wang L, Zhou W, Yuan S. Canonical correlation study on the relationship between shipping development and water environment of the Yangtze River. Sustainability. 2020; 12: 3279, doi:10.3390/su12083279.

Sansawat A, Tangjuang P, Sayompark D. Effect of Basella spp. fruit powder on the physicochemical, sensory and microbiological properties of goat milk yoghurt. Int J Dairy Sci. 2022; 17(1): 24-32.

Schoffel A, Lopes SJ, Koefender J, Dal'Col Lúcio A, Golle DP, Camera JN. Canonical correlations between traits of cassava plants propagated by an adaptation of rapid multiplication method. Rev Ceres. 2023; 70(3): 136-146.

Tipkanjanarat P, Wasusri T. Correlation analysis between water quality factors and chemical usages with canonical correlation technique in Metropolitan Waterworks Authority. J KMUTNB. 2015; 25(3): 405-414 (in Thai).

Vargas J. Using canonical correlation analysis to understand the rumen biohydrogenation patterns of linoleic and alpha-linolenic acids in the rumen fluid of bovines. Acta Sci – Anim Sci. 2023; 45, e57724, https://doi.org/10.4025/actascianimsci.v45i1.57724.