Egyptian J. Camel Sci., **3**, No.2, 67-76 (2025)

EVALUATE THE QUALITY OF CAMELS', GOATS' and SHEEP'S MILK by VISION SYSTEM and SPECTROPHOTOMETER

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ABSTRACT

To assess the quality of raw camels', sheep's and goats' milk, the chemical composition and color were measured using computer vision systems (CVS) and conventional colorimetry as a reliable indicator. Cluster analysis was utilized to identify the similarities between the species. The findings indicate that there is a distinct difference between species. camel milk had a whiter color than sheep and goat milk, in the same order. However, colorimetry highlights a greater similarity between sheep and goat milk. The variables that were the most similar were fat, protein, a*, and b*, while composition and colorimetry were the most distinguishing, while the type of milk was the least. The colorimetric variables were highly linked to milk solids in all species, and all types of milk had an inverse relationship with lactose, pH, and L*. Moreover, there was a significant correlation between color and chemical composition for all species. CVS imaging has the capacity to estimate the technological value of milk, which demonstrates the usefulness of calorimetry for dairy manufacturers. Helping to make quality assessment of these products easy, quick, and cost-effective is essential.

Keywords: Image processing, quality. Camels', goats' and sheep's milk.

INTRODUCTION

Color is a way to assess food quality in the food industry. The first quality attribute for consumers is its appearance, taste, and aroma (Wu and Sun, 2013). Quality assurance programs consider both chemical composition (fat and protein content) and sanitary parameters (somatic cell counts) of milk to ensure high quality. (Gonzalo et al. 2006). Color analysis is a common tool in the food processing sector (Agudelo-Laverde et.al, 2013). Food quality improvement has been achieved by food industry members through the development of color measurements for food products. The International Commission on Illumination (CIE) has set specific criteria for color assessment to achieve the highest level of product acceptance and quality. Bimpilas et al. (2016) Observed that colorimeters and spectrophotometers are common color measurement tools in the food industry. However, these tools are not suitable for all products. Colorimetric has seen evolution in the use of computer vision systems (CVS) to measure color parameters (Minz and Saini, 2021 and Al-Hilphy et al., 2022). This system uses digital images and records it as values for the primary colors of light, namely red, green, and blue (RGB) (Wu and Sun, 2013). CVS uses an algorithm to convert color values from RGB to CIE Lab (L*, a* and b*), facilitating rapid color measurement (Aghbashlo et al., 2014, Minz and Saini, 2021). CVS has been used in the food field to measure color in various items. This includes vegetables and fruits (Zhang et al., 2014), baked goods (Nashat and Abdullah, 2010), meat (Tomasević et al., 2019), dairy and its products (Minz and Saini, 2021).

The color of milk can be considered an indicator of the quality of cow's milk, as studies have shown a direct relationship between milk composition and its color indices (McDermott et al., 2016). Figueroa et al. (2020) demonstrated that the composition and coagulation properties of sheep milk can be predicted using color parameters. Also, Milovanovic et al., (2020) mentioned that the differences in milk types are linked to the characteristics of each type, which affect color indices. Additionally, Garzón et al. (2024) explained that analytical studies of color and coagulation properties identify similarities and differences, both in color and those affecting the coagulation process to assess and, subsequently, improve manufacturing quality.

The objective of this study was to assess the correlation between camels' goats' and sheep's' milk in terms of composition, color, and determine if these characteristics have an impact on milk quality.

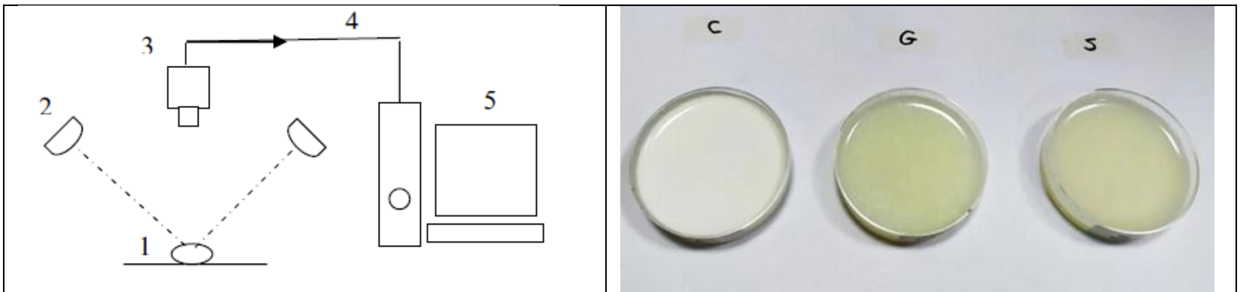
MATERIALS AND METHODS

1- Samples of milk

Goats' and sheeps' milk samples were collected from Halaib and Shalateen Areas particularly in Halaib Research Station, Desert Research Center (located in Southeastern Egypt between latitudes 23-22 South in the zone of Elba Natural Reserve. They are following The Red Sea Governorate). While camels' milk was collected at random from camel-rearing areas around Halaib and Shalateen Districts. Goat and sheep were fed on concentrating feed mixture, but camels were fed free pasture. The milk samples were immediately maintained and stored under refrigerated conditions delivered to the laboratory for analysis within 24 h. The physical characteristics of various milk samples were determined according to AOAC, (2023). The total solids, total nitrogen (using micro-Kjeldahel method) and ash (using Thermolyne, type 1500 Muffle Furnace) contents, acidity, as well as pH values were determined by using digital pH meter (Inolad model 720, Germany) in fresh milk treatments according to the method of AOAC, (2023). Determination of the total fat content of the sample was done by modified Gerber Method (Singh, 2014). Total carbohydrates were calculated by the difference for all samples analyzed.

Image processing

The processing of an image starts with the transfer of the image to the PC, where the image analysis process is applied, as shown in figure 1.



1- Milk sample 2- Light Source 3- Digital camera 4- Connecting wire 5-Computer	S: Sheep milk, G, Goat milk, and C, Camel milk

Fig. 1. Vision, illumination, color analysis systems, and different milk types.

After that, analysis performed to the watermark to determine if each pixel belongs to color. The parameters obtained from each milk sample (in each image are the pixel number of lighter or darker of milk sample. Taking images of each milk sample, a total number of 6 parameters can be obtained.
Digital camera: A digital camera was used to take a photo image for each sample. For position adjustment of image, a stand camera was used in order to fix the distance between digital camera and milk sample to be 26 cm, resolution and intensity of light (530 lux).

2- Color analysis

Hunter lab color, Different milk samples were evaluated for colour using Hunter lab colour. (model D25) colour according to hunter methods and color scales shown in Figs. 1 and 2. (Nozière et al., 2006). The Hunter colour values of produced milk samples were measured based on three parameters, the L, a, and b types of scales simulate as: L (Lightness): is the ranging from 0 for black (darker) color to 100 for white (lightness) color; a (red-green) : is the ranging from (–a) for greens to (+a) for redness, and b (blue-yellow) is the ranging from (– b) for blueness to (+b) for yellowness.

Whiteness index (WIE), whiteness is a color index, which a sample is judged to approach the preferred white. A single number (WIE) is used as a measurement of whiteness according to (Vargas et al, 2008). The WIE can be calculated using equation (1)

$$WIE = 100 - ((100-L^*)^2+(a^*)^2+(b^*)^2)^{0.5} \quad (1)$$

Hue degree (φ), hue angle may be defined as the angle between the hypotenuse and 0° on the a (blue-green/red-yellow) axis, however, positive value use in the first and third and negative values in the second and fourth the quadrants, according to Bermúdez-Aguirre *et al.* (2009). Hue angle, can be computed from the following equation (2) $\varphi = \arctan(b^*/a^*)$ (2)

Saturation (σ), saturation was referred to colour saturation or intensity according to Vargas et al. (2008). This can be calculated from the following equation (3) and represents the hypotenuse of a right triangle created by joining points (0,0), (a, b), and (a,0).

$$\sigma = (a^2 + b^2)^{1/2} \quad (3)$$

The total color difference (ΔE) was used to evaluate the general colour differences between spectrophotometer and CVS colour values according to Bermúdez-Aguirre et al., (2009) and Milovanovic et al. (2021). Three readings per sample were measured using a spectrophotometer and three images were acquired using CVS. ΔE was calculated using the following equation:

$$\Delta E = ((L_s - L_c)^2 + (a_s - a_c)^2 + (b_s - b_c)^2)^{0.5} \quad (4)$$

where, L_s, a_s , b_s are L∗, a∗, b∗ colour values measured using a spectrophotometer. L_c , a_c , b_c are L∗, a∗, b∗ colour values measured using CVS.

L∗ = 0 to 100 a∗ = − 120 to + 120 b∗ = − 120 to + 120 ΔE = 0 to 354

3- Statistical analysis

The results obtained were subjected to analysis of variance (ANOVA) for comparison of means with Duncan's multiple ranges. Also, multivariate analysis techniques to analyze the differences and similarities in type of milk, milk composition and colour values to evaluate the specific relationships between those factors by cluster analysis and Pearson correlation. All statistical analyses were performed using SAS version 12.1 (SAS, 2012).

RESULTS AND DISCUSSION

Chemical composition of milk

Table 1 shows the results of the chemical composition of camels', goats', and sheeps' milk. The results indicate that there was a significant difference (p≤ 0.001) in fat, protein, carbohydrates, and total solids. However, the differences in ash and pH were not significant (p>0.05). Additionally, camel milk had the lowest fat content sheeps' and goats' milk. On the other hand, sheeps' milk had the highest levels of protein, carbohydrates, and total solids, followed by goats' and camels' milk. For carbohydrate content, goats' milk ranked highest, followed by sheeps' and camels' milk. There were similarities in the chemical composition of sheeps' and goats' milk, likely due to their physiological similarities and production conditions (Leitner et al. 2016). Overall, the chemical content of camel, goat, and sheep milk in this study fell within the range reported by Khaskheli et al. (2005) and Barłowska et al. (2011).

Table 1: physico-chemical of milk sample

Group	pH	Fat (%)	Protein (%)	Ash (%)	Total carbohydrates (%)	Total solids (%)
Camel milk	6.67	2.63^b	3.27^c	0.81	4.87^c	11.58^c
Goat milk	6.64	3.45^a	3.60^b	0.84	5.45^a	13.30^b
Sheep milk	6.65	4.45^a	4.05^a	0.90	5.00^b	14.40^a
±SE	0.14	0.37	0.09	0.03	0.14	0.62

$^{a-c}$ Superscript lowercase letters in each column indicate statistically significant difference (P < 0.05)

Interrelationships between Color and Composition from camels', goats' and sheeps' milk

The results in Table (2) present the color readings obtained from a conventional colorimeter and the CVS for camels', goats', and sheeps' milk. The white color of milk, indicated by the L* value, comes from the fat globules and casein micelles that scatter visible light (Owens et al., 2001). The findings revealed that the lightness (L*) values of camels' milk samples (85.21 and 86.40) were lighter than those of sheeps' (78.74 and 80.69) and goats' milk (76.53 and 77.87), regardless of whether conventional or CVS colorimetric methods were used. This might be due to the smaller size of fat globules (Sunita et al., 2014, Li et. al., 2023) and casein micelles (Swelum et al., 2021) in camels' milk compared to those found in goats' and sheeps' milk (Attaie and Richter, 2000 and Ingham et al., 2018). Also, Chudy et al., (2020) demonstrated that milk lightness increases with a decrease in its β-lactoglobulin content. Camels' milk lacks β-lactoglobulin, which increases its L* (Swelum et al., 2021).

Table (2) Color values of camels', goats' and sheeps' milk samples

	L	a	b	WIE	Saturation	Hue	DE
colorimetric							
Camels'	85.21^{b}	0.99^{d}	3.38^{e}	85.28^{a}	3.52^{e}	1.29^{bc}	
Goats'	76.53^{f}	5.02^{b}	18.15^{c}	69.90^{d}	18.83^{c}	1.30^{abc}	
Sheeps'	78.74^{d}	3.66^{c}	14.10^{d}	74.22^{b}	14.57^{d}	1.32^{ab}	
±SE	0.272	0.214	0.407	0.497	0.429	0.017	
CVS							
Camels'	86.40^{a}	1.31^{d}	4.03^{e}	85.75^{a}	4.25^{e}	1.26^{c}	1.46^{c}
Goats'	77.87^{e}	7.87^{a}	25.94^{a}	64.99^{e}	27.11^{a}	1.28^{c}	3.41^{a}
Sheeps'	80.69^{c}	4.93^{b}	20.23^{b}	71.60^{c}	20.82^{b}	1.33^{a}	2.42^{b}
±SE	0.149	0.117	0.223	0.198	0.235	0.009	0.150

$^{a\text{-}f}$ Superscript lowercase letters in each column indicate statistically significant difference ($P < 0.05$)

The results also showed that sheep milk had a lower L* than camels' milk but a higher L* than goats' milk when measured with either colorimetric method. This occurs because sheeps' milk has a higher fat and protein content, along with higher vitamins and lower carotene, compared to goats' milk (Chang et al., 2020; Laurent et al., 2023), which contributes to its yellow color. The scattering of white light seems to arise from the colloidal casein bonds in casein micelles. Natural pigments in milk appear to affect redness (a*) and yellowness (b*). This was evident in the yellowing degree (b*) caused by milk carotenoids, which was highest in goat milk, followed by sheeps' milk, and then camels' milk. The results further showed that the L*, a*, and b* parameters were higher with CVS than with the traditional colorimetric method. These findings matched those of Sethi et al. (2016) and Milovanovic et al. (2021) regarding color assessment of goats' and sheeps' milk and other dairy products using CVS and colorimeters. These results were the opposite of those shown by Milovanovic et al. (2020). They demonstrated that goats' milk had a higher L* than both sheeps' and camels' milk, but the a* and b* values were similar to the results in the study. In general, differences in color parameters come from many factors, including genetics, nutrition, and the chemical composition of the milk (Walker et al. 2013 and Scarso et al. 2017).

The results showed that the color index (WI) whiteness is responsible for the milk's whiteness, which comes from light reflecting off the sample. There is an inverse relationship between light scattering and the components of milk. As a result, camel milk is whiter than sheeps' and goats' milk. The WI depends on the components of milk, such as fat, protein, salts, and lactose, which affects the whiteness of the sample (Milovanovic et al., 2021). The WI index was higher when using CVS compared to the traditional colorimetric method.

These low values indicate minimal reddish and yellowish hues, suggesting a color close to a neutral white standard. This finding is supported by the lowest saturation values (3.52 and 4.25) and ΔE values (1.46 for CVS), confirming that camel milk has a low-chroma color that is least distinct from a theoretical white. Many descriptions of camel milk emphasize its pure white appearance (Jand and Mir, 2017).

Since milk color is always distinct, it was necessary to check the color differences between the colorimetric method and CVS. A clear difference was found among the various types of milk studied. This was shown by the low ΔE value (<1.5) for the camera used in CVS when measuring camels' milk and slightly perceptible through close observation (Cserhalmi et al., 2006). In contrast, the ΔE values (1.5-3) for sheeps' is a perceptible but ΔE values (3 - 6) for goats' milk is highly or very perceptible (Cserhalmi et al., 2006). This difference arises from how deeply light penetrates the sample, how much it scatters and reflects, and the chemical makeup of the sample. The lower the brightness values, the lower the opacity, leading to greater light transmission. These values were similar to those found by Milovanovic et al. (2021).

Correlation Matrix for Physico-Chemical and Color Variables

Based on the data provided table (3) contains calculating a standard Pearson correlation matrix for the physico-chemical and color variables across the three milk types. This analysis provides an indication of how the mean values of these properties relate to each other.

Strong Positive Correlations: Variables like protein, ash, total solids, a*, b*, saturation, hue, and DE show extremely strong positive correlations with fat. This indicates that as the fat content in the milk increases (from camel to goat to sheep), these other properties also tend to increase in value. The color values a *, b*, saturation, hue, and DE are all highly correlated with each other, suggesting that milk with a more intense and distinct color also tends to have a higher degree of redness and yellowness. These results are consistent with Garzón et al. (2024) in goats' and sheeps' milk.

Strong Negative Correlations: There is a very strong negative correlation between L* and WIE and the color values a*, b*, Saturation, Hue, and DE. This is expected, as high lightness and whiteness index implies a less intense, less yellow and reddish color.

Weak Correlation: The pH value shows a relatively weak correlation with fat and total carbohydrates. However, it has strong negative correlations with most other variables, which suggests that milk with a higher pH value (less acidic) tends to have a high lightness color and lower nutrient content, this was evident in camel milk. These results are consistent with Yalçin (2025) to Awassi ewes milk quality.

Table 3. Standard Pearson correlation for the relationships between composition and CVS.

	pH	Fat (%)	Protein (%)	Ash (%)	Total carbohydrates (%)	Total solids (%)
pH	1.00	-0.17	-0.63	-0.62	-0.99	-0.32
Fat (%)		1.00	0.98	0.97	0.05	0.99
Protein (%)			1.00	1.00	0.49	1.00
Ash (%)				1.00	0.47	1.00
Total carbohydrates (%)					1.00	0.20
Total solids (%)						1.00
L*	0.90	-0.89	-0.97	-0.97	-0.79	-0.94
a*	-0.95	0.96	1.00	1.00	0.90	0.99
b*	-0.97	0.96	0.99	0.99	0.94	0.99
WIE	0.92	-0.91	-0.98	-0.98	-0.82	-0.96
Saturation	-0.96	0.96	0.99	0.99	0.93	0.99
Hue	-0.93	0.98	1.00	1.00	0.88	1.00
DE	-0.97	0.95	0.99	0.99	0.94	0.98

It performed a hierarchical cluster analysis on the data provided and generated a dendrogram for type of milk samples, composition and colorimetric properties, that are easily noticeable (Figure 2). A dendrogram is a tree-like diagram that visualizes the results of hierarchical clustering. The vertical axis represents the Euclidean distance (or Hartigan Index), which measures the dissimilarity between clusters. The horizontal axis shows the milk samples.

(a) Cluster Analysis for the Whole Set of Variables: When considering all physico-chemical and colorimetric variables together, camels' milk is distinct and forms its own cluster, as it is quite different from both goats' and sheeps' milk. Goats' milk and sheeps' milk are more similar to each other and are grouped together, indicating they share more overall characteristics than does with camels' milk. These results are consistent with Garzón et al. (2024) in goats' and sheeps' milk.

(b) Cluster Analysis for Composition Variables: When only considering composition variables (pH, Fat, Protein, Ash, etc.), the pattern is similar. Camels' milk again forms a distinct cluster from the other two. Goats' and sheeps' milk are closely related, with the clustering suggesting they have a more similar nutritional and physical composition than with camels' milk. This is likely driven by higher fat, protein, and total solids content in both goats' and sheeps' milk compared to camels' milk.

(c) Cluster Analysis for Colorimetric Variables: The cluster analysis of the colorimetric variables (L*, a*, b*, etc.) reveals a different grouping. Camels' and sheeps' milk are grouped together, while goats' milk forms a separate cluster. This result indicates that camels' and sheeps' milk share similar color properties, while goats' milk has a unique color profile. This aligns with the data provided, where goats' milk shows a higher a* and b* value, indicating a more reddish yellow color, which makes it distinct from the whiter camels' and sheeps' milk samples.

Thus, it can be said that cluster analysis demonstrated the extent of similarity between the different types of milk studied. A clear distinction can be made between camels' milk and both sheeps' and goats' milk. There is a similarity in composition between goats' and sheeps' milk, which is due to the nature of nutrition and the evolutionary closeness between the two species, which is not limited to physiological similarity but also includes similar animal and husbandry practices (Leitner et al. 2016). Pearson correlation model shows that the color indices (a* and b*) are strongly correlations with milk components (fat, carbohydrate, protein, total solids, and ash), while they were inversely correlated with L* for all milk types (Solah,et al 2007).

CONCLUSION

In this study, the color of sheep, goat, and camel milk samples was measured using CVS and color spectrophotometry. Even though the same criteria were used to evaluate the color of camels', goats', and sheeps' milk, such as the D25 light source, measurement area, resolution, and intensity of light, the color analysis provides robust evidence for significant differences in the visual properties of camels', goats', and sheeps' milk. Camels' milk is characterized by its high lightness and low chroma, presenting as the whitest and most neutral of the three. Goats' milk, conversely, is distinguished by its intense yellowish-reddish hue, making it the most colorful and visually distinct. Sheeps' milk occupies an intermediate position. Variations likely influence these color differences in the composition of these milk types, including levels of fat, protein, and pigments like carotenoids and riboflavin. Goat and sheep milk show similarities in their composition, while colorimetry suggests a greater similitude between camels' and sheeps' milk. There is a strong positive relationship common to protein, ash, total solids and fat. Color variables were closely related to fat and protein content in camels', goats' and sheeps' milk. It has been demonstrated that CVS can serve as a substitute for color spectrophotometry in measuring the color of different milks. It is cost-effective, quick, and can be used to evaluate milk quality. It can be concluded that the color measuring by CVS, important in dairy products, can determine animal health and the quality of raw milk, and provides an indicator for improving the productivity of various dairy products. Thus, it contributes to evaluating the quality of products, as well as their storage in an easy, quick, and cost-effective.

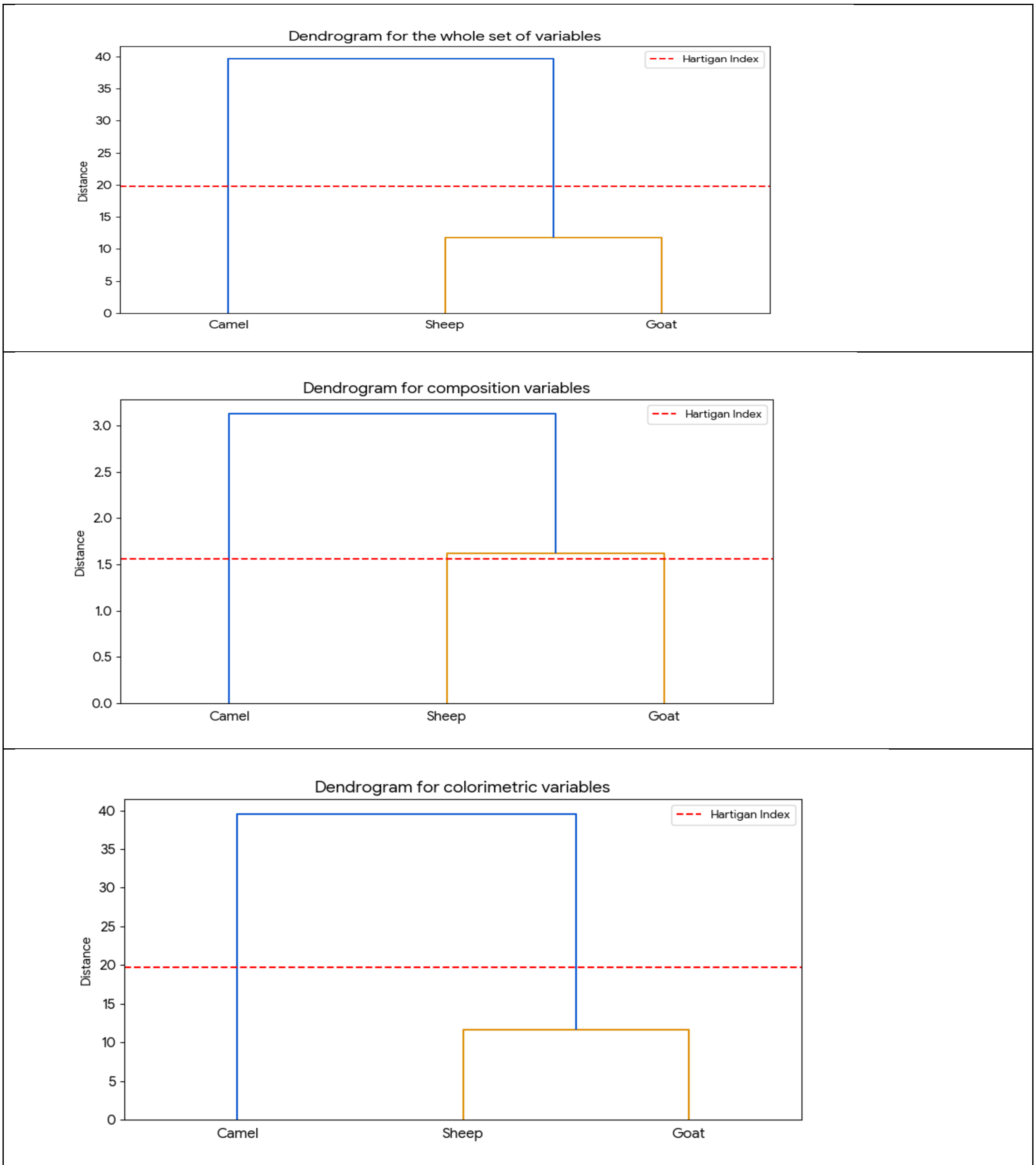


Fig (2): Representation of the results from cluster analysis for (a) the whole sets of variables; (b) composition variables; (c) colorimetric variables. Different colored lines with different groups according to the Hartigan index (represented by a dashed line).

Acknowledgement: The authors are thankful staff into Laser Application in Agricultural Engineering Lab, National Institute of Laser Enhanced Sciences (NILES), Cairo University, Egypt., for providing laser lab measurements. Department of Animal Breeding, Desert Research Center, Egypt., for save samples and physic-chemical analysis. Agricultural Engineering Research Institute, Agriculture Research Center for supporting lab facility

Conflicts of Interest: The authors declare no conflict of interest.

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الملخص العربي

تقييم جودة حليب الإبل والماعز والغنم عن طريق نظام الرؤية الحاسوبية ومقياس الطيف الضوئي

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لتقييم جودة حليب الخام للإبل والمعز والغنم، تم قياس التركيب الكيميائي واللون باستخدام أنظمة الرؤية الحاسوبية (VCS) وقياس الألوان التقليدي كمؤشر موثوق بة. تم استخدام التحليل العنقودي لتحديد أوجه التشابه بين الأنواع. وتشير النتائج إلى وجود فرق واضح بين الأنواع، حيث كان لون حليب الإبل أكثر بياضًا من حليب الغنم والمعز، بنفس الترتيب. ومع ذلك، يسلط قياس الألوان الضوء على تشابه أكبر بين حليب الغنم والمعز. وكانت المتغيرات الأكثر تشابهاً هي الدهون والبروتين و*a و*b، في حين كان التركيب وقياس اللون الأكثر تميزاً، في حين كان نوع الحليب هو الأقل. وارتبطت المتغيرات اللونية بشكل كبير بمواد الحليب الصلبة في جميع الأنواع، وكان لجميع أنواع الحليب علاقة عكسية مع اللاكتوز، ودرجة الحموضة، و*L. علاوة على ذلك، كان هناك ارتباط كبير بين اللون والتركيب الكيميائي لجميع الأنواع. يتمتع تصوير CVS بالقدرة على تقدير القيمة التكنولوجية للحليب، مما يدل على فائدة قياس اللونى لمصنعي الألبان. مما يساعد على جعل تقييم جودة هذه المنتجات سهلاً وسريعًا وفعالاً من حيث التكلفة.
الكلمات المفتاحية.:

الكلمات الدالة: معالجة الصور، جودة ، لبن الإبل ، لبن المعز، لبن الغنم