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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Traditional Machine Learning-Based Classification of Cashew Kernels Using Colour Features

Kaju Çekirdeklerinin Renk Özellikleri Kullanılarak Geleneksel Makine Öğrenmesine Dayalı Sınıflandırılması

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Abstract

Cashew is one of the major commercial commodities contributing to the national economy of Tanzania as foreign revenue. And yet still the processing of cashew is run locally using manual labour for a big part. If processed well under ideal conditions, cashews kernels are expected to be white in colour. But due to various factors like prolonged roasting in the steam chambers or over-drying, some cashew kernels tend to have a slight brown colour, and these are referred to as scorched cashews. Despite sharing the same characteristics with white cashew kernels, including nutritional quality, these cashew kernels are supposed to be graded differently. In many places around the world, particularly in Tanzania, the sorting and grading process of cashew kernels is performed by hand. In international trade, cashew grading is very important and this means more effective and consistent methods need to be applied in this stage of production in order to increase the quality of the products. The objective of this study was to evaluate the use of traditional Machine Learning techniques in the classification of cashew kernels as white or scorched by using colour features. In this experiment, various colour features were extracted from the images. The extracted features include the means (μ), standard deviations (σ), and skewness (γ) of the channels in RGB and HSV colour spaces. The relevant features for this classification problem were selected by applying the wrapper approach using the Boruta Library in Python, and the irrelevant ones were removed. 5 models are studied and their efficiencies analysed. The studied models are Logistic Regression, Decision Tree, Random Forest, Support Vector Machine and K-Nearest Neighbour. The Decision Tree model recorded the least accuracy of 98.4%. The maximum accuracy of 99.8% was obtained in the Random Forest model with 100 trees. Due to simplicity in application and high accuracy, the Random Forest is recommended as the best model from this study.

Keywords: Logistic Regression, Decision Tree, Random Forest, Support Vector Machine K-Nearest Neighbour, Cashews

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* This study is summarized from the MSc. thesis.

Öz

Kaju, Tanzanya'nın ülke ekonomisine dış gelir olarak katkı sağlayan başlıca ticari ürünlerden biridir. Kaju çekirdeklerinin işlenmesi, halen büyük ölçüde el emeği kullanılarak yerel olanaklarla yapılmaktadır. İdeal koşullarda iyi işlenirse kajuların beyaz renkte olması beklenir. Ancak, buhar odalarında uzun süre kavurma veya aşırı kurutma gibi çeşitli faktörler nedeniyle, bazı kaju çekirdekleri hafif kahverengi bir renge dönüşebilmektedir. Renk değiştirmiş bu kajulara kavrulmuş kaju denir. Besin kalitesi de dahil olmak üzere beyaz kaju çekirdekleri ile aynı özelliklere sahip olmasına rağmen, renk ve görünüm tüketicilerin kalite algısını etkilediği için bu kaju çekirdeklerinin ayrılması gerekmektedir. Tanzanya başta olmak üzere dünyanın pek çok yerinde kaju çekirdeklerinin ayırma ve sınıflandırma işlemi elle yapılmaktadır. Uluslararası ticarette, kaju sınıflandırması çok önemli olup ürün kalitesini artırmak için üretimin bu aşamasında daha etkili ve tutarlı yöntemlerin uygulanması gerektiği anlamına gelir. Bu çalışmanın amacı, kaju çekirdeklerinin beyaz veya kavrulmuş olarak sınıflandırılmasında renk özellikleri kullanılarak geleneksel Makine Öğrenmesi tekniklerinin kullanımının değerlendirilmesidir. Bu çalışmada, görüntülerden farklı renk özellikleri çıkarılmıştır. Çıkarılan özellikler, RGB ve HSV renk uzaylarında kanalların ortalamaları (μ), standart sapmaları (σ) ve çarpıklığını (γ) içerir. Python'da Boruta Kütüphanesi kullanılarak sarmal (*wrapper*) yöntemi uygulanarak bu sınıflandırma problemi için ilgili özellikler seçilmiş ve ilgili olmayanlar çıkarılmıştır. Bu çalışmada 5 model çalışılmış ve verimlilikleri analiz edilmiştir. Değerlendirme teknikleri Lojistik Regresyon, Karar Ağacı, Rastgele Orman, Destek Vektör Makinesi ve K-En Yakın Komşu (KNN) yöntemleridir. Karar Ağacı modeli, %98,4 ile en düşük doğruluğu vermiştir. 100 ağaçlı Rastgele Orman modelinde maksimum %99,8 doğruluk elde edilmiştir. Uygulamadaki basitliği ve yüksek doğruluğu nedeniyle Rastgele Orman bu çalışma için en iyi model olarak önerilmektedir.

Anahtar Kelimeler: Lojistik Regresyon, Karar Ağacı, Rastgele Orman, Destek Vektör Makinesi ve K-En Yakın Komşu (KNN), Kaju fıstığı

1. Introduction

The cashew tree (*Anacardium occidentale*) is an evergreen tropical tree of the *Anacardiaceae* family that produces cashew nuts and cashew apples. This tree can grow to a height of 8-20 m depending on different factors like climate and soil characteristics, also there are dwarf cultivars that can be as short as 6 m (Catarino et al., 2015). In general, all types of nuts have numerous health benefits to humans (Karcık and Taşan, 2018). With different kinds of nuts in the market like, pistachios, macadamias, peanuts, almonds and hazels, the low sugar, rich fibre, heart-healthy fats and plant protein content of cashew nuts make them one of the most edible nuts in the world (Kilanko et al., 2020). Tanzania is one of the cashew producers in the world and due to its good soil condition and favourable weather, Tanzania is famous for producing premium quality cashew nuts. Cashew nut plays a major role in Tanzania's economy as one of the main cash crops, in the season 2019/20 about 232.7 tons of cashew were produced showing an increase in production from the previous crop season where 225.1 tons were produced as indicated in (*Figure 1*), (Faria, 2021). Cashew nut processing can be summarized into six steps which are roasting, cutting, drying, humidifying, peeling and grading (Muniz et al., 2006). In order to meet international standards, the grading process becomes a crucial part so, it has to be done carefully (Kumar et al., 2013). Based on their size, shape and colour cashew kernels are visually inspected and graded into grades. Currently, in many places the sorting and grading process is done manually by using human labour, this makes the process tedious, subject to human errors, inconsistent as well as time-consuming and this raises a concern to apply automated ways to perform this task (Mehak and Veena, 2018). The use of mechanization for agriculture production has a crucial significance in the quality of the product (Özpınar and Çay, 2018). And as mechanization is for human physical labour, so is artificial intelligence for human mind labour.

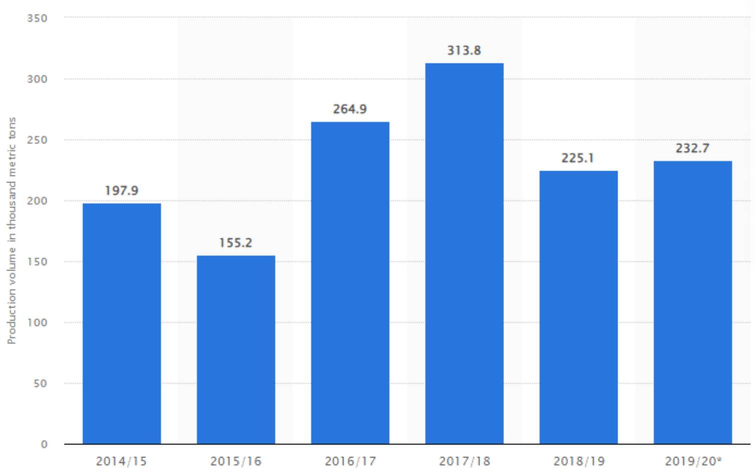

Figure 1. Cashew production in Tanzania between 2014 and 2020 (Faria, 2021).

Computer-based vision and machine vision technologies are relatively economical, consistent, flexible and reliable and have over and over proven to have superior accuracy (Du et al., 2016). Ahmadabadi et al., (2017) used Support Vector Machine to design and develop an online grading system for peeled pistachio nuts equipped with machine vision technology. Various models with different kernel functions were developed and tested, and the highest accuracy of 99.17% was obtained from a model using the cubic polynomial kernel function. Nagpure and Joshi (2016) also did a study to grade cashew nuts on the bases of colour, texture and size by applying the K-Nearest Neighbours classifier. A Feed-Forward Neural Network model using colour features extracted from Red Green Blue (RGB) images was used to classify cashew kernels into six grades with a classification rate of 80% (Ganganagowdar and Siddaramappa, 2011a). Also, another study was done to classify white whole cashew kernel using texture features. In this study, a Multilayer Feed-Forward Neural Network was used, and the accuracy of this algorithm was 90% (Ganganagowdar and Siddaramappa, 2011b). A novel intelligent model extracted 24 colour and 16 morphological features of the cashew kernel and used a Multilayer Perceptron ANN to recognize and classify white wholes into different grades using a Backpropagation learning algorithm and attained a classification of 88.93% (Ganganagowdar and Siddaramappa, 2016). Vidyarthi et al. (2020) applied four different deep Convolutional Neural Network models, which are VGG-16, ResNet50, Inception-V3 and a custom model to classify cashew kernels into five categories. The overall minimum accuracy of all the models was 95.1%. A study was done by Aran et al., (2016) to find out the effect of different features in the grading of the cashew kernel. In this study, colour, texture, shape and size features were extracted and tested on five different classification algorithms (i.e., Random Forest, Multilayer Perception, Multi-class classifier, Regression and Backpropagation Neural Network (BPNN)). The results revealed that BPNN had the best accuracy of about 96.8%. Sunoj et al., (2018) used the morphological features and shadows from cashew kernel images to classify whole and split cashew kernels. In this study, a single point light source inclined at 56° was used to generate cashew shadows, which were then processed in the ImageJ plugin. The classification algorithm developed in this study used object shadows and surface grayscale-intensity-profile for the whole and split-up cashews, respectively, and it had a 100% accuracy. Babu et al. (2012) developed an intelligent classifier model by extracting colour features of the cashew kernel and passing them as inputs into the Neural Network system. The system had an accuracy of 86% in classifying the cashew kernels into different grades. Mehak and Veena (2018) implemented two classification techniques to develop an accurate and efficient classification model for industrial cashew kernel grading. Eight cashew grades were used in this study. Support Vector Machine had an accuracy of 85% when running with the One-vs-All algorithm. When the One-vs-One algorithm was used, the accuracy increased to 90.6%. The highest accuracy observed in this study was in the Random Forest classifier, where the maximum recorded accuracy was 94.28%. Nadar and Kundargi (2018) used the Bayes algorithm to build a classification model in MATLAB 7.8 to classify the cashew kernels by analysing the shape parameters of the cashew kernel (i.e., length (L), width (W) and thickness (T)). Another study was performed by Thakkar et al. (2011) to evaluate the performance of different classification algorithms in cashew nuts grading systems. In this study, the physical properties of the cashew kernels were extracted and used as attributes for the classification model. Various classification algorithms were tested, including; ML-Perceptron KNN, Naive Bayes SVM and Decision Tree. The results of the study were as follows; ML-Perceptron had a classification accuracy of 86%, Decision Tree-79%, K-Nearest Neighbour- 76%, Naïve Bayes-81% and SVM had an accuracy of 77%.

Computer vision has been widely applied in agricultural product inspection, and more studies are still being carried out to improve this technology. In the experiments listed above, we can see how various textural, morphological, colour features have been used to classify the cashew kernels in different ways. Most of the studies performed used representational machine learning approaches to classify the cashew kernels. There has not been an experiment done to study the effect of colour features in the classification of cashew kernels using traditional machine learning. In this study, the main objective was to study the usefulness of the colour features in the classification of cashew kernels into white and scorched categories. The emphasis was put on using traditional machine learning-based algorithms to classify the cashew kernels instead of using the representational machine learning algorithms. The algorithms were written using the Python programming language and run in Spyder integrated development environment.

2. Materials and Methods

2.1. Experiment samples

The cashew kernel samples were obtained from the Tanzania Agricultural Research Institution Centre in Naliendele (TARI Naliendele), located at **10° 22′ 20“S, 40° 10′ 34“E** along the coastal belt of the Indian Ocean. The samples were raw and included the scorched and white whole classes of cashew kernel. The samples were inspected and stored at room temperature. A total of 1000 cashew kernels (both white and scorched) were collected for the experiment.

2.2. Image acquisition

Like other computer vision studies, the first step was the acquisition of samples' images. In this experiment, a high-resolution Guppy Pro F-032 camera was utilized to capture the images and store them in Portable Network Graphics file format (PNG). The size of the image used was 120x120. By using a tripod stand, the camera was fixed at a constant distance from the base, where the samples were placed. A black surface was used as a background in this experiment. Proper lighting is very essential in acquiring images with the best quality. In this experiment, two 8-watt fluorescent lamps were used as the source of light in the image acquisition chamber.

2.3. Image pre-processing and segmentation

After the image acquisition process, the images may need to be pre-processed to make the following steps free of error and easier. Noise is one of the most unavoidable problems in image acquisition. So, after the images were captured, they were pre-processed to remove noise. Later, image segmentation was performed to remove the background of the image retaining only the object of interest while keeping the colour information of the original cashew kernel after segmentation. To achieve the image segmentation process, the system should first detect the object from the background. Threshold segmentation technique was applied in this study, as explained by (Dong et al., 2013). Various threshold values were tested until an optimal threshold value with maximum spread between the foreground and the background was found.

2.4. Feature extraction and feature selection

The features used in this study to classify the cashew kernels were the colour features of the cashew kernels. A wide range of colour features can be extracted from an image, but the colour moments are the most prominent features that can define the characteristics of the image. Among the colour moments, the most important ones used in image retrieval applications are the low order moments. Different colour features were extracted from the captured images and the features that were extracted in this experiment include the means (μ), standard deviations (σ), and skewness (γ) of the red (R), green (G) and blue (B) channels from the RGB colour space, the hue (H), saturated (S) and value (V) channels from the HSV colour space, the excess blue (2B-G-R), excess green (2G-R-B) and excess red (2R-G-B). The mean (μ), standard deviation (σ), and skewness (γ) of the pixels in the image were calculated using the following equations, respectively (Aran et al., 2016).

$$Mean(\mu) = \sum_{j=1}^{N} \frac{1}{N} P_{ij} \quad \text{(Eq.1).}$$

$$Standard\ deviations\ (\sigma) = \sqrt{\left(\frac{1}{N}\sum_{j=1}^{N}(P_{ij} - E_i)^2\right)} \quad \text{(Eq.2).}$$

$$Skewness\ (\gamma) = \sqrt[3]{\left(\frac{1}{N}\sum_{j=1}^{N}(P_{ij} - E_i)^3\right)} \quad \text{(Eq.3).}$$

A total of 21 features were extracted from the images. To improve the efficiency of a classification model and decrease the running time, it is highly recommended to use only the important features and get rid of irrelevant features. This process is called feature selection. In this experiment, feature selection was done in Python using the Boruta Library, which uses the wrapper approach to select the relevant features by building a random forest classifier.

2.5. Classification models

With the development in technology, the invention of machine learning has proven to be very useful in different areas. Machine learning generally means the computer can learn to perform a particular task without being detailed programmed to do so. Firstly, the computer learns from specific data then it can work on new data on its own. Generally, we can group machine learning models into two groups depending on the kind of data fed into the system. The first type is traditional machine learning. These are algorithms that usually use numerical features as input. In traditional machine learning, the choice of the algorithm and the input data (features) to be used is determined by the expert. On the other hand, we have representational machine learning which can take unstructured data like videos and photos as input and learn from these data the significant features to focus on without the expert having to extract and specify the features. In this experiment, five traditional machine learning models were tested and studied for classifying the cashew kernel into white and scorched classes using the selected colour features. These models are Logistic Regression, Decision Tree, Random Forest, Support Vector Machine and K-Nearest Neighbour model.

3. Results and Discussion

3.1. Data collection

Out of the 1000 collected cashew kernels samples, 812 were selected and captured for the experiment. 402 of the captured images were scorched and 410 were white. (*Figure 2*) shows an example of the images captured in this experiment. 67% of these samples were used for training the model, the rest 33% were spared for testing the model.

Figure 2. Sample of the captured cashew kernels scorched nut on the left, white nut on the right.

3.2. Image segmentation

Different threshold values were tested to segment the foreground from the background in Python and the threshold of 60 was found to have the best performance. This threshold value was used to segment the images in a sense that the pixels with intensity value less than 60 were not processed and those with intensity value greater than 60 were assigned a constant value to create a mask that can be applied to the original image to segment the foreground from the background. (*Figure 3*) show the stage an image went through from an original image to the segmented image both for white and segmented.

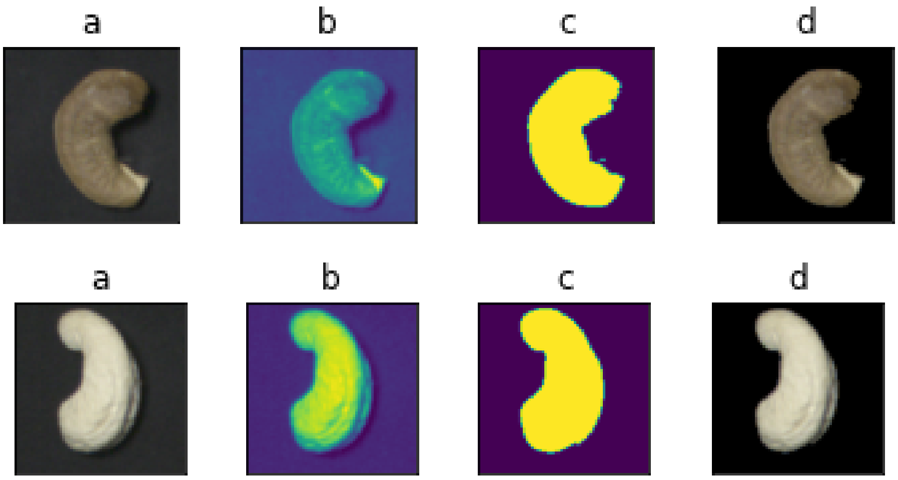

Figure 3. Raw image segmentation stages

3.3. Feature selection and extraction

This experiment used the colour features of the cashew kernels to classify them into white or scorched categories. 21 colour features were extracted and after evaluating the effectiveness of all features in predicting the category of the cashew kernels only 14 features were found to have a significant effect and the other irrelevant 7 features were left out. (*Table 1*) below shows the list of features used and those left out.

Table 1.List of accepted and rejected features

No.	Feature	Status	No.	Feature	Status
1.	Red Mean	Rejected	12.	Excess Blue	Rejected
2.	Green Mean	Rejected	13.	Hue Mean	Accepted
3.	Blue Mean	Accepted	14.	Saturated Mean	Rejected
4.	Red Std	Accepted	15.	Value Mean	Rejected
5.	Green Std	Accepted	16.	Hue Std	Accepted
6.	Blue Std	Accepted	17.	Saturated Std	Accepted
7.	Red Skewness	Accepted	18.	Value Std	Accepted
8.	Green Skewness	Accepted	19.	Hue Skewness	Accepted
9.	Blue Skewness	Accepted	20.	Saturated Skewness	Accepted
10.	Excess Red	Rejected	21.	Value Skewness	Accepted
11.	Excess Green	Rejected			

3.4. *Classifiers*

Five traditional Machine Learning models were evaluated in this study, the classification accuracy, recall, precision and F1_score were used for comparison of the models. (*Table 2*) below shows a summary of classification report for all the models tested. The first model was Logistic Regression, the accuracy of this model from the validation was found to be 99.6%. (*Figure 4*) below shows the confusion matrix of the Logistic Regression model for this classification problem.

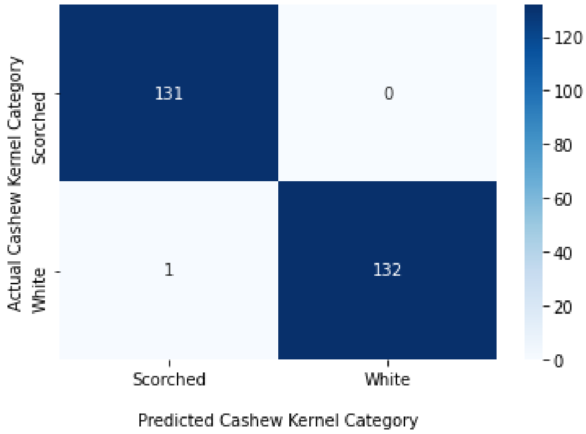

Figure 4. Logistic Regression model confusion matrix

The second model to be tested was the Decision Tree model. The classification Decision Tree implicated in this experiment used the Gini impurity as a deciding factor at the split nodes. The accuracy of the Decision Tree in this experiment was found to be 98.1%. (*Figure 5*) below shows the confusion matrix of the Decision Tree model for this classification problem.

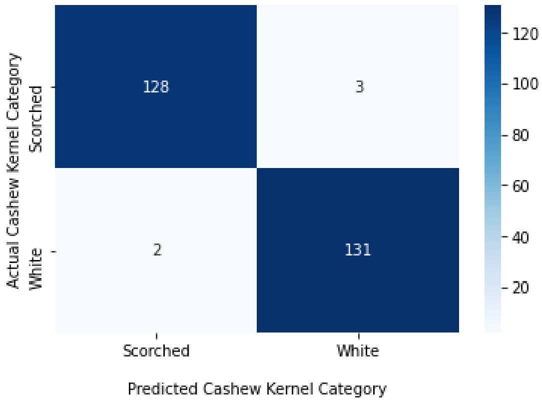

Figure 5. Decision Tree model confusion matrix

A Random Forest is a correction of many decision trees so, it is an improvement of the Decision Tree method. First, a Random Forest with 10 trees was used and the accuracy was 98.5%. Later the number of trees was increased to 100 trees, and the accuracy elevated to 99.8%. (*Figure 6*) below shows the confusion matrix for the two Random Forest models tested for this classification problem.

A Support Vector Machine was also used in this classification. The accuracy of the Support Vector Machine algorithm was 99.6%. (*Figure 7*) below shows the confusion matrix of the Decision Tree model tested for this classification problem.

Last but not least, the samples were tested in the K-Nearest Neighbour algorithm. First, the value of K was set to 7 and the accuracy of the system was found to be 98.8%. Upon decreasing the value of K to 5 the accuracy increased to 99.5%. The maximum accuracy was obtained after lowering the value of K down to 3 where we got 99.7% accuracy. (*Figure 8*) below shows the confusion matrix for the three KNN models tested for this classification problem.

(*Table 2*) show the summary of the test algorithms with their performance accuracies, recall, precision and F1 scores.

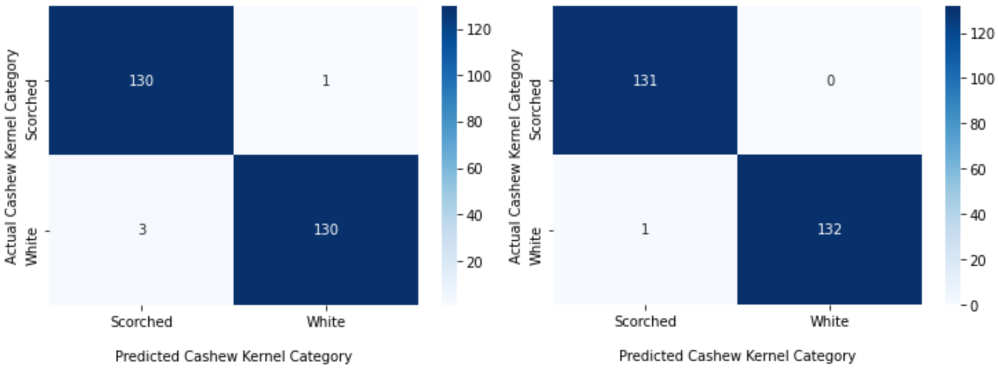

Figure 6. Random Forest model confusion matrix (10 trees on the left, 100 trees on the right)

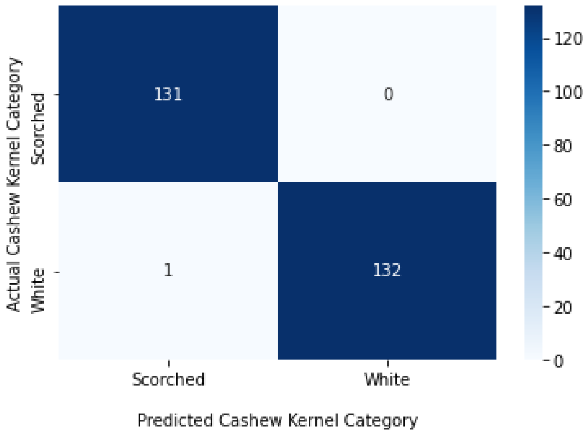

Figure 7. Support Vector Machine model confusion matrix

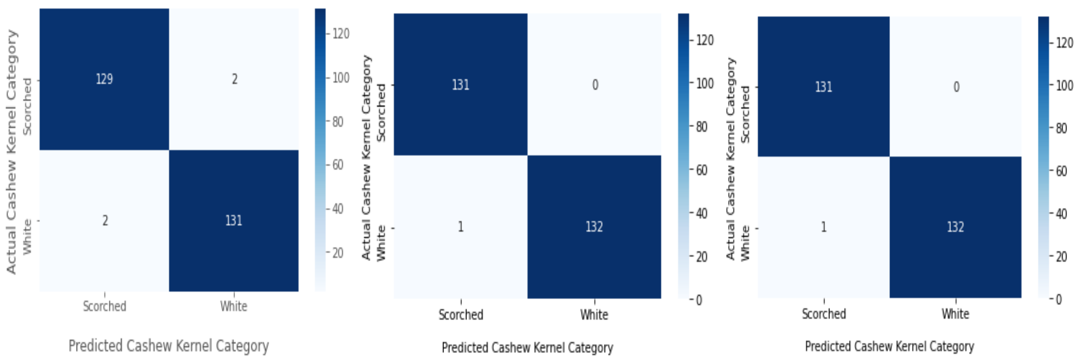

Figure 8. KNN model confusion matrix (K=7 on the left, K=5 on the centre, K=3 on the right)

Table 2. Classification performance of the tested model

No.	Classification Method		Classification Accuracy	Recall	Precision	F1_score
1.	Logistic Regression		99.6%	0.9925	0.9987	0.9962
2.	Decision tree		98.1%	0.9849	0.9776	0.9812
3.	Random Forest	10 Trees	98.5%	0.9774	0.9923	0.9848
		100 Trees	99.8%	0.9924	0.9991	0.9982
4.	Support Vector Machine		99.6%	0.9925	0.9987	0.9962
5.	K- Nearest Neighbour	K= 7	98.8%	0.9874	0.9922	0.9898
		K= 5	99.5%	0.9901	0.9989	0.9951
		K= 3	99.7%	0.9913	0.9990	0.9975

4. Conclusion

Cashew kernel classification is still a very big problem in many places where manual labour is used extensively. This means that still there is a need to apply computer vision-based classification techniques to help improve the efficiency of the classification process as well as lower the overall operation costs. This study aims to evaluate the effectiveness of colour features in the classification of cashew kernel into white and scorched categories. From the results obtained, the colour features have proved to be effective in the classification of the cashew kernels into these two categories. All the tested traditional Machine Learning techniques have given promising results in this classification. Random Forests are usually easy to construct and with the accuracy obtained in this study, it would be more practical to prefer Random Forest for this classification.

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