**Automated detection of softening and hard columella in kiwifruits during postharvest using X-ray testing**

Germán Mondragón[a], Gabriel Leiva[b], José Miguel Aguilera[b], Domingo Mery[a]

[a] *Department of Computer Science, Pontifical Catholic University of Chile, Santiago, Chile (gmondrag@uc.cl)*
[b] *Department of Chemical and Bioprocess Engineering, Pontifical Catholic University of Chile, Santiago, Chile (gmleiva@uc.cl)*

## INTRODUCTION

Flesh and columella firmness variability in kiwifruit affects its postharvest quality. Kiwifruit are climacteric fruit which may be stored during six months before commercialization. It is desirable to maintain its flesh firmness high during the first time and to control the softening during the last time. Columella firmness should be near to flesh firmness at the end of the maturity. These two problems are invisible to the naked eye and mechanical methods are slow and destructive. X-rays images may be an industrial solution to improve kiwifruits postharvest storage and quality measuring firmness level and columella incidence.
The objective of this work was to design a methodology for sorting kiwifruits in different flesh and columella firmness levels with X-ray image processing and pattern recognition techniques.

## MATERIALS & METHODS

Kiwifruis (200 unities) were store at 20 °C during 20 days to induce different firmness states. Samplings were done every three days and consisted in acquire two x-ray images per kiwifruit (X-ray Source: A battery powered X-ray system Poskom XM-20BT, Flat Panel Detector: Cannon CXDI-50G. Parameters: 3.6 mA – 40 kV and 5.0 mA – 50 kV each image) and one visible internal image (kiwifruits were cut at the half and the cross section was imaged) to measure columella area (DVS-lab colorimeter, www.divisol.cl). After image acquisition, each fruit was firmness measured (8 mm punction test in texturometer TA.TX2i (Stable Micro Systems, Surrey, UK) in flesh and columella according to previous studies [1] to correlate images information with traditional parameters to train image processing algorithms. All the images were processed using statistical recognition pattern algorithms [2] (Balu toolbox, Matlab, Mathworks corp.) to classify images in four steps: Image segmentation [3]; feature extraction features selection [4]; and classifiers design. All de result was validated using stratify 10 fold "cross-validation" with 95% confidence and confusion table.

## RESULTS & DISCUSSION

Features reduction: Features were reduced from 572 to 20 allowing faster future applications in process sorting lines. These only twenty features allow a well classification in the most of the cases. Is interesting to understand that all images were in intensity and due to technical characteristics of x-ray equipment, the images seem at first sight to be similar each other.
Flesh firmness classification after harvest: Flesh firmness after harvest was 42.4 +- 12.1 N showing a considerable variability. To diminishing variability and extend shelf life a special selection stage in process lines is required. With this argument in mind, 42.4 N was established as the inferior limit to obtain a "softening free kiwifruit class" immediately after harvest. In this

sense, computer vision techniques applied in this study was able to classify over 93 % fruit softening free using selected classifiers: Neunetglm,3 network net (NN) and Linear discriminant analysis (LDA). Columella firmness at the end of Postharvest: Firmness of columella is an important quality attribute for consumers. At the end of accelerated storage, the columella firmness was 56.7 +- 28.9 N. superior limit of columella firmness was arbitrarily established 27.8 N, as an acceptance limit to design a segregation plan before consume. LDA classify over 93.9% kiwifruits unities with hard columella. Classifying big and short columella: X-rays images processing of whole kiwifruits also allowed classify two groups of columella cross area kiwifruits "cross average area superior" and "cross average inferior" with NN obtaining 94.6 % of yield (average cross columella area was 358 $mm^2$).

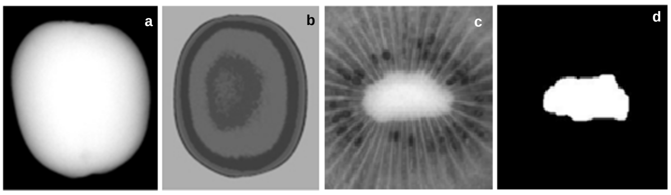


**Figure 1.** Typical x-ray kiwifruit image (a); Colour segmentation kiwifruit x-ray image (b); columella(c); Columella segmented (d)

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Other studies have shown the efficacy of x-rays images to reveal internal characteristics of fruits to measure insects develop [5], but using in kiwifruit to detect soft and hard tissue and columella size is new and promises x-ray non-destructive use in other fruits.

## CONCLUSION

Despite kiwifruit firmness is high variable and its traditional measures are destructive, the presented results with a non destructive technology are promissory. This study is the first approach to diminishing operations cost and rejections of kiwifruit batches in destine using non invasive x-ray computer vision techniques to segregate different qualities of kiwifruits after harvest.

## REFERENCES

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