# Calibration of Microwave Meter to Measure Kernel Moisture Content of Inhull Almonds


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## ABSTRACT

For quality almonds growers and processors need to measure and control kernel moisture content. Hence, the almond industry needs to pursue opportunities to measure and control almond moisture content throughout the value chain. The USDA has developed a microwave moisture meter for peanuts and almonds (kernel and inshell). The unit passes microwaves through a 120 mm thick sample of 4.5 liters in volume and measures the absorption of the microwaves by the water in the fruit. The aim of this work was to develop a calibration to obtain almond kernel moisture from inhull almonds. Results showed that prediction of kernel moisture content from inhull measurements had a standard error of calibration of 0.24% and a worst case accuracy of ± 0.6% mc. These tests on different varieties show that a separate calibration will be required for some varieties due to compositional differences.


## INTRODUCTION

Moisture content of the kernel of almonds is an essential quality parameter that almond growers and processors need to measure and control. If moisture content is too low, the grower loses some value of his crop and the kernels become brittle and can easily be damage in processing. If kernel moisture content is too high, the almond will degrade quickly and can cause spoilage of the almonds. Thus kernel moisture must be at or below 6%[1].

Almond moisture meters currently in the market use radio frequency (RF) to determine moisture content For these meters, it is required to physically separate the kernel of the almond from the shell and hull. The kernels are placed inside the machine and a moisture content value is derived. These sensors operate by creating a capacitor with the material placed between the two electrodes. The capacitance value is obtained and correlated to the moisture content.

The USDA has developed and patented a microwave moisture meter[2] for peanuts and almonds. Here the moisture measurement is obtained by measuring the transmission of electromagnetic energy through the material. The frequency of the energy is 5.8 GHz which is very sensitive to water. Dielectric properties are fundamental properties that describe a dielectric material's interaction with an electric field given by the following equation

$$\varepsilon = \varepsilon' - j\varepsilon''$$

where,

- the real part. $\varepsilon'$ is defined as the dielectric constant, which is associated with the electric energy stored in the material.
- the imaginary part $\varepsilon''$ is the dielectric loss factor, which is associated with the energy lost in the material.
- $j$ is the imaginary unit.

Dielectric properties of a material are dependent on many factors including frequency, moisture content, temperature, and density. Since the dielectric constant of water ($\varepsilon'$ = ~80) is relatively large versus that of dry organic matter ($\varepsilon'$ = ~1-2), moisture content measurement is possible.
Further improvement can be obtained with a density-independent parameter ψ (psi), where

$$\psi = \sqrt{\frac{\varepsilon'}{\varepsilon''(a_f\varepsilon' - \varepsilon'')}}$$

where $a_f$ is the slope of the regression line formed when plotting the dielectric constant divided by density, $\varepsilon'/\rho$, versus the dielectric loss factor divided by density, $\varepsilon''/\rho$, in the complex plane[2].

## OBJECTIVES

- The object of this three month project was to develop a calibration data set for the USDA microwave moisture meter to measure the moisture content of inhull almonds from hull split to dried.
- The work focused primarily on the Nonpareil variety of almonds but also looked at other major varieties as time allows.


## ACKNOWLEDGEMENTS

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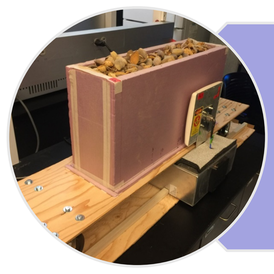
california almonds Almonds.com


## MATERIALS AND METHODS

Nonpareil Inhull almond samples were collected from Nickels Soil Laboratory in Arbuckle, CA. Butte and Monterey Inhull almonds were received from a producer in Glenn, CA.

Samples were conditioned to specific moisture contents using a constant humidity chamber.



Measurement of dielectric properties of inhull almonds performed using USDA microwave moisture meter.


**Figure 1. USDA microwave moisture meter.**

## RESULTS AND DISCUSSION

Figure 2 shows the linear relationship between moisture content and psi (ψ) that can be used to calibrate the microwave moisture meter.

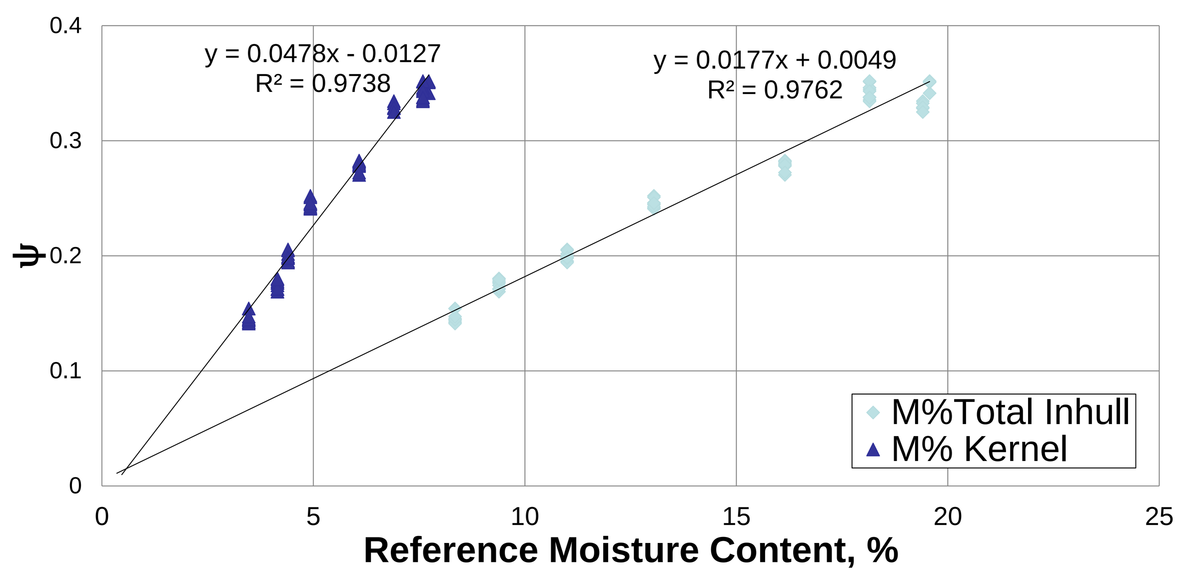



**Figure 2. Results of calibration of inhull Nonpareil almonds.**

Figure 3 shows the accuracy of moisture prediction using the inhull calibration data. Further work can be done to improve the maximum ± 0.6% variation.

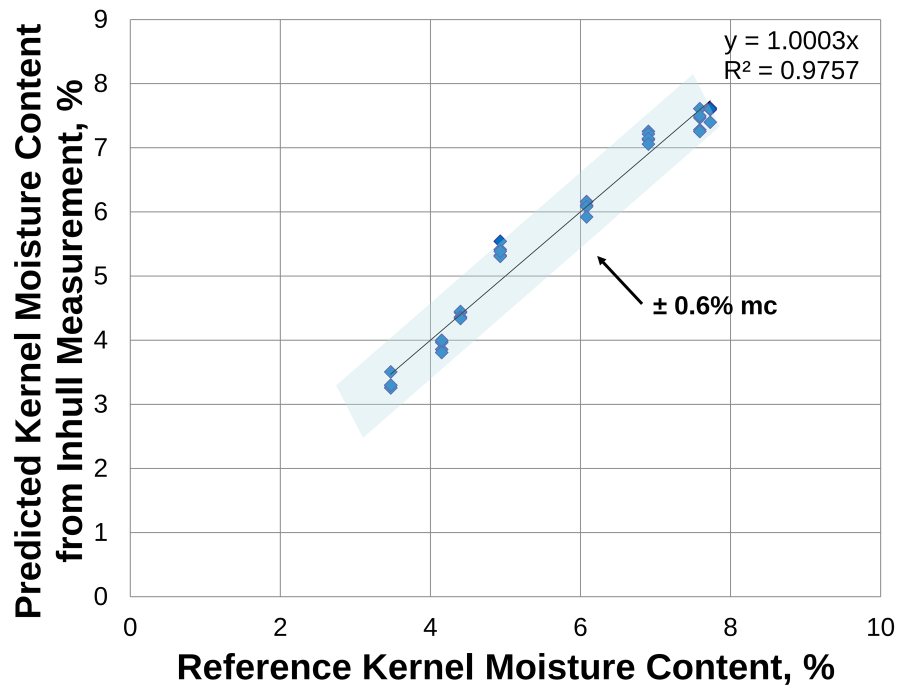



**Figure 3. Accuracy of moisture prediction of current set up.**

## RESULTS AND DISCUSSION (cont.)

Figure 4 shows the effect of almond variety on moisture calibration. The difference in calibration can be explained by the variation in the proportions of hull, shell and kernel (see Figure 5).

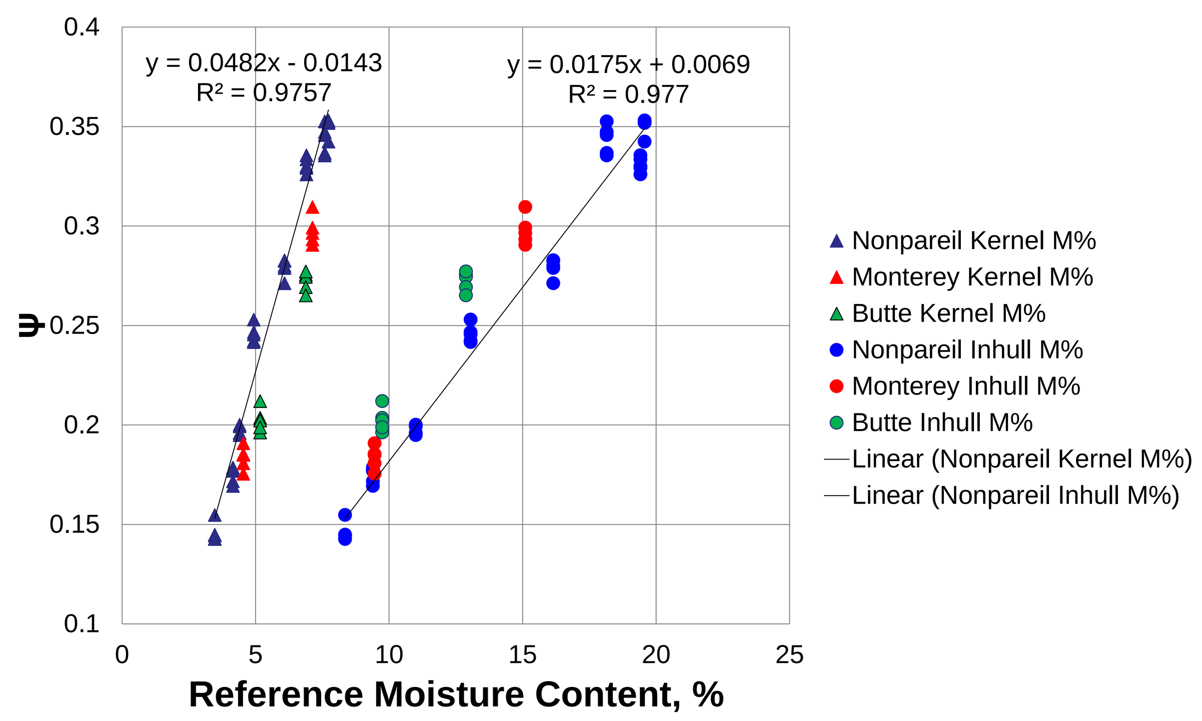



**Figure 4. Calibration differences for the varieties of Nonpareil, Butte and Monterey.**

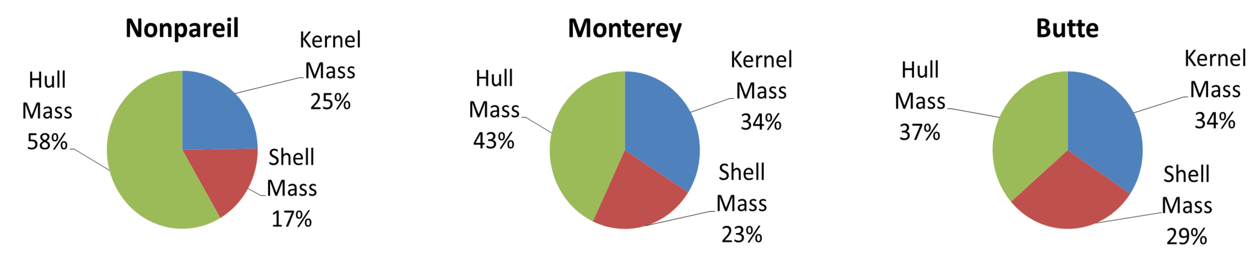



**Figure 5. Differences in the mass percentage of each constituent component of inhull almonds for three almond varieties.**

Thus, the variability in almond composition requires another calibration dataset to be used if the composition changes.

Figure 6 shows how the equilibrium relative humidity within the almond sample can be used to predict kernel moisture content for the almond forms of kernel, inshell and inhull. This could present an inexpensive method for determining moisture content for almonds in storage.

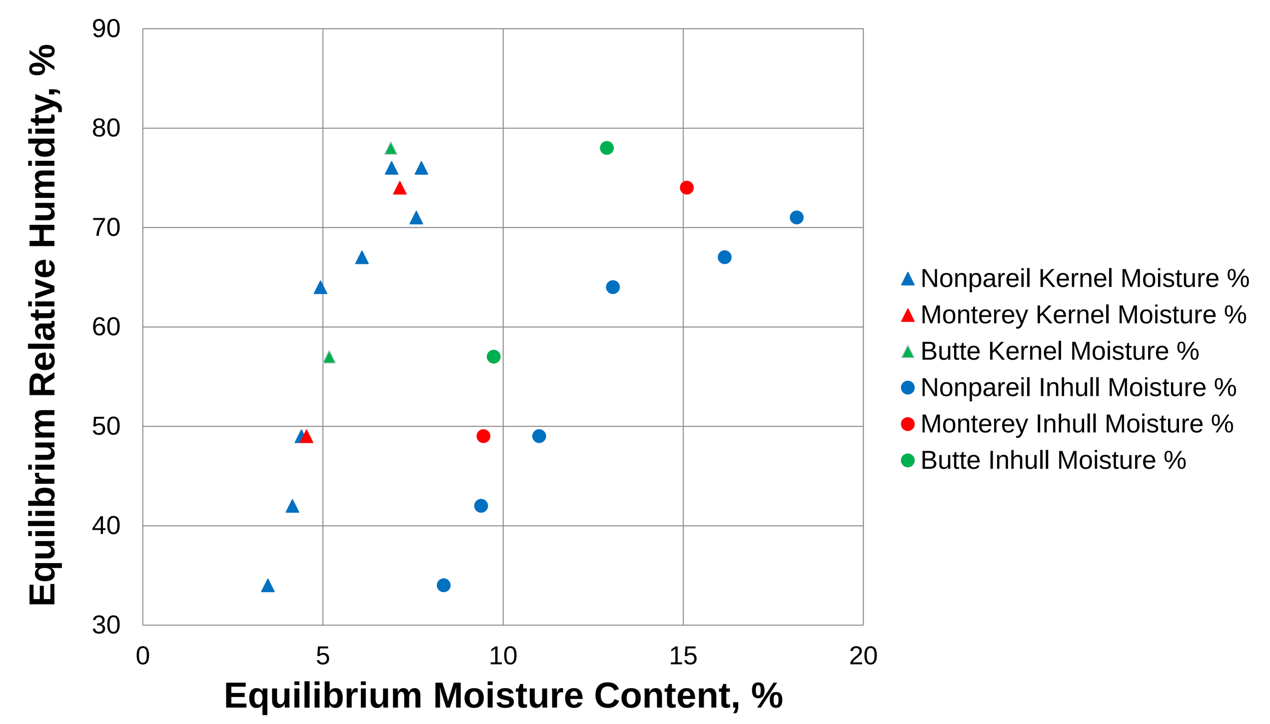



**Figure 6. Equilibrium kernel and inhull moisture contents plotted against equilibrium relative humidity.**

## CONCLUSIONS

The project achieved its aims of developing calibration curves to measure the kernel moisture content from inhull samples. For this to be achieved a sample of almonds must pass between the antennas, lending itself to an in-line moisture meter for almond flow. This could be used on an almond pickup/conditioner to measure kernel moisture as almonds are picked up in the orchard or at other times of handling and processing almonds.

It is recommended that work be continued to develop the calibrations and equipment concepts into a machine useful to industry.


## REFERENCES

[1] Dingke, Z., & Fielke, J. (2014). Some physical properties of Australian Nonpareil almonds related to bulk storage. *International Journal of Agricultural and Biological Engineering*, *7*(5), 116.

[2] Trabelsi, S., & Nelson, S. O. (2014). *U.S. Patent No. 8,629,681*. Washington, DC: U.S. Patent and Trademark Office.