Assessment of wax coatings in postharvest preservation of the pea (*Pisum sativum* L.) var. Santa Isabel

Evaluación de recubrimientos céreos de arveja (*Pisum sativum* L.) var. Santa Isabel para conservación en poscosecha

Luis Gabriel Padilla T.[1] and Jorge Humberto Zurita V. (†)[2]

ABSTRACT

The 'Santa Isabel' pea is the most sown regional variety in Colombia. In order to evaluate the postharvest behavior of 'Santa Isabel', an experiment was conducted that subjected fresh podded peas to different edible wax-coating treatments (Taowax verduras, Ceratec, Ceratec wwd (without washing or disinfection), castor oil, and mineral oil) and compared them to treatments with the non-edible wax Cerabrix grees or without waxing (control). The peas were stored in a growth chamber for 2 weeks at a temperature of 7±2°C and a relative humidity of 70±8%. The coating of the pods significantly decreased the loss of fresh weight in the six treatments with coatings, as compared to the control (without coatings). The wax coatings that lost less water included Cerabrix grees (7.78%) and Taowax verduras (10.65%), as compared to the control (37.79%). The pH of the grains generally decreased during the 14 days of storage; however, after 10 days, the peas coated with Ceratec and Ceratec wwd again increased the pH of the grain. Furthermore, all of the coatings demonstrated a low incidence of pathogens in the pods, with the better results occurring in the non-edible Cerabrix grees and the edible Taowax verduras; the latter wax also had a good aroma, appearance, and color.

Key words: waxing, pod, grain, weight loss, pH, aroma.

RESUMEN

La arveja 'Santa Isabel' es la variedad regional más sembrada en Colombia. Con el fin de evaluar el comportamiento poscosecha de 'Santa Isabel se realizó un experimento en el cual se sometieron frutos de arveja en fresco con vaina a tratamientos de encerado con cinco recubrimientos céreos comestibles diferentes (Cerabrix grees, Taowax verduras, Ceratec, Ceratec sld (sin lavado y desinfectado), aceite de higuerilla y aceite mineral) comparado con el recubrimiento no comestible Cerabrix grees y sin recubrir (testigo). Se almacenaron las arvejas en una cámara de crecimiento a temperatura de 7±2°C y humedad relativa de 70±8% durante 2 semanas. El recubrimiento de las vainas disminuyó significativamente la pérdida de peso fresco en los seis tratamientos con encerado comparado con el testigo. Los recubrimientos céreos que menos agua perdieron fueron Cerabrix grees (7,78%) y Taowax verduras (10,65%), comparado con el testigo (37,79%). El pH del grano, en general se redujo durante los 14 días del almacenamiento, sin embargo, después de los 10 días las arvejas recubiertas con Ceratec y Ceratec sld aumentaron de nuevo su pH del grano. Además, todos los recubrimientos mostraron una menor incidencia de los patógenos sobre las vainas, con los mejores resultados para el no comestible Cerabrix grees y el comestible Taowax verduras, esta última cera también tenía buen aroma, apariencia y color.

Palabras clave: encerado, vaina, grano, pérdida de peso, pH, aroma.

Introduction

The pea (*Pisum sativum* L.) is one of the more important horticultural crops in Colombia. According to Agronet (2014), in 2014, Colombia produced 55,959 t in an area of 33,631 ha, mainly in the departments of Nariño, Boyaca, Cundinamarca, Tolima and Huila. The pea is notable for its high protein content in the grains, which can reach 24% (Ligarreto, 2012). The principal destination of Colombian pea production is fresh consumption (Duarte *et al*., 2006). It presents good palatability and, using the fresh, green grain, it can be frozen, rehydrated, dried, and used as a flour, fresh pod, or peas (Ligarreto, 2012).

The regional variety Santa Isabel, chosen for this experiment, has the largest cultivated area in Colombia and has 120 d till harvest for green grains, 170 d till harvest for dried grains, and an adaption range of 2,400 to 2,700 m a.s.l. (Duarte *et al*., 2006). In addition, this pea is notable for its good commercial characteristics, such as large pods and grains, being one of the more profitable varieties for green

Received for publication: 23 July, 2014. Accepted for publication: 30 March, 2015. Doi: 10.15446/agron.colomb.v33n1.44543

[1] Scheelea Group S.A.S. Chia (Colombia). lgpadillat@gmail.com
[2] Department of Agronomy, Faculty of Agricultural Sciences, Universidad Nacional de Colombia. Bogota (Colombia)

pods in the country, and its dried grains are characterized by round, smooth shapes and a dark cream color (Ligarreto and Ospina, 2009).

The pea is highly perishable considering that this species was classified by Kader (2002) into the group of green vegetables that has the highest respiration rate (>60 mg CO_2 kg^{-1} h^{-1} at 5°C) but lack a climacteric peak.

When offering a safe or innocuous product, the preservation of the freshness of fruits and vegetables with the use of edible coatings is constantly gaining relevance for the market and consumers (Velásquez *et al.*, 2014). From the development stage until senescence, the leaves and fruits secrete and deposit hydrophobic cuticle waxes on the epidermis in order to prevent losses through transpiration and restrict the exchange of gases and the entrance of pathogens (Schopfer and Brennicke, 2006; Tafolla-Arellano *et al.*, 2013). Herrera (2012) considered the transpiration of a product to be the most important cause of quality loss and loss of commercial value in fresh vegetables, as seen in weight loss, less consistency, and withering, which drastically affect the appearance.

Harvested products are generally subjected to a process of washing and disinfection, which eliminates part of the natural wax that covers the susceptible areas during the postharvest life and protects against pathogen attacks, making it necessary to apply wax coatings as a commercial practice in order to restore the natural protection that interferes with the regulation of CO_2 and O_2 exchange with the environment in the harvested product (Gutiérrez, 2004; Olivas *et al.*, 2008; Yahia *et al.*, 2011).

Olivas *et al.* (2008) classified edible coatings as hydrocolloid compounds (polysaccharides and proteins), hydrophobic compounds (lipids and waxes), or a combination of both (coating compounds). Falguera *et al.* (2011) noted important characteristics in edible coatings, such as a barrier that restricts the flow of gasses, a structural resistance against water and microorganisms and sensorial acceptance; however, waxes must permit the entrance of a certain quantity of O_2 and exit of CO_2 for the aerobic respiration process (Ahmad and Khan, 1987) and, in addition, waxes must form an effective barrier against water vapor, avoiding weight loss through transpiration (Ortolá and Fito, 2001).

Orjuela-Baquero *et al.* (2014) noted that the superficial wax coating of fruits and vegetables with different types of coatings generates a modified passive atmosphere around the product, favoring many characteristics for a reduction in losses of fresh weight and lower respiration rates, considering that the combination of wax coatings and storage at low temperatures produces favorable effects on the product quality and postharvest longevity.

Taking into account the fact that wax coatings consist of distinct compounds and application methods and that protected vegetable products are diverse, living organs, the ability of the coatings to preserve the quality of fruits and vegetables depends on the coating method, the formulation of the coating, the characteristics of the plant product and the postharvest conditions (Olivas *et al.*, 2008).

As a result, this study aimed to evaluate the behavior of five different wax coating products in order to determine which coatings produced better preservation of the podded peas so that a better shelf-life can be maintained with less weight loss and a better product presentation.

Materials and methods

Santa Isabel variety podded peas were used, harvested at physiological maturity during January on the Scheelea farm in the municipality of Chia (Colombia), at 4°51' N and 74°03' W and 2,590 m a.s.l. with an average annual temperature of 13°C. The plant material was packed in Styrofoam coolers with ice in order to reduce moisture losses and losses through respiration.

After harvest, the legumes were transported to the Laboratory of Physiology of the Faculty of Agricultural Sciences of the Universidad Nacional de Colombia, Bogota, where an initial selection was carried out in order to prevent the preliminary and latent appearance of fungi.

The 28 experimental units were weighed with a semi-analytical balance (precise to two decimal places). Afterwards, the waxes were applied using the following treatments, with four replications for each one (Tab. 1).

The application of the coatings was carried out with the injection of polyurethane foam in order to form a protective layer on the vegetative product so that the shelf-life could be prolonged, whose function is to replace the natural wax of the vegetable that was lost in the process prior to the wax coating (Tao Química, 2007b) and to protect the products from microorganisms (Hortitec de Colombia, 2007).

All of the treatments were introduced into a Biotronette® Mark II (Lab-Line Instruments, Chicago, IL) refrigerated plant growth chamber where they were subjected to a temperature of 7±2°C and a relative humidity of 70% (±8%) for 14 d.

TABLE 1. Treatments, compositions and doses of the applied waxes.

Treatment number and wax	Composition	Dose	Source
Cerabrix grees	Solution of modified natural resin based on solvents, modified natural resin and ammonium hydroxide, non-edible	1 L of pure product	Tao Química, 2007a
Taowax verduras	Solution of modified natural resin with a solubility that formed a creamy solution in water, edible	1 L of pure product	Tao Química, 2007b
Ceratec, with washing and disinfecting of the peas	Emulsion of waxes and lipids for agricultural use, edible	500 mL of Ceratec/1,500 mL of water	Hortitec de Colombia, 2007
Ceratec wwd (without washing or disinfection of the peas)	Edible	500 mL, pure	Hortitec de Colombia, 2007
Castor oil	Oily solution of *Ricinus communis* L. with a natural, vegetative origin with a homogenous, translucent, slight viscous liquid aspect, edible (USP grade)	500 mL, pure	Disproalquímicos, 2007
Mineral oil	Oily solution of a natural mineral origin fabricated with a paraffin base and a refining process using solfonation and extraction in order to eliminate sulfur, polynucleic, aromatic hydrocarbon and unsaturated compounds, edible (USP grade)	500 mL, pure	Químicos y Cápsulas, 2007
Control	No wax coating		

For the physicochemical characteristics, the pH of the grains was evaluated at 5, 10 and 14 d after the start of the experiment using a Beckman pHI31 pHmeter (Beckman Coulter, Brea, CA) in 10 g of podded peas in each of the experimental units (two peas in a pod), which were peeled and ground in a mortar with 10 mL of distilled water.

The weight loss was evaluated as a percentage between days 0 and 3, 3 and 5, 5 and 7, 7 and 10, 10 and 12, and, finally, between days 12 and 14 from the start of the experiment. The characteristics aroma, appearance, pod color, pod texture, grain maturity, and appearance of pathogens were evaluated with a value scale (Tab. 2).

Statistical analysis

The experimental unit contained 240 g of podded peas, distributed in seven treatments including the control. Each treatment was repeated four times and the treatments were subjected to a completely randomized design. The pH and percentage of weight loss data were analyzed with Statistical Analysis System SAS® Version 9.1, applying ANOVA and the statistical differences of the means were compared with the Tukey method ($P\leq0.05$).

Results and discussion

Weight loss

During the experiment, there was a general tendency for gradual weight loss, naturally due to transpiration and respiration (Kader, 2011). In all of the coatings, it was observed that the coated podded peas lost less weight than the peas without a coating (Tab. 3), probably due to a reduction in the permeability of water vapor and of gas exchange between the plant material and the environment or surroundings (Dhall, 2013). It is well-known that wax coatings on vegetable products form a barrier against water vapor, avoiding weight loss through transpiration (Ortolá and Fito, 2001).

In all of the time intervals, the moisture loss of the coated peas was significantly lower ($P\leq0.05$) than in the untreated pods (control) (Tab. 3), observing a small loss between days 3 and 5 of storage; the pods probably tried to adapt to the new environment with a low temperature (7°C) by forming a barrier against gas exchange. After 5 d, an increase in water loss was observed, with the highest value between 7 and 10 d and a mean of 3.34%, which constantly decreased afterwards to 1.78% on 14 d. This pattern of increase and

TABLE 2. Value scale for the organoleptic and physical characteristics.

Score	Aroma	Appearance	Pod color	Pod opening	Grain maturity	Appearance of pathogens
20	Very fresh	Excellent	Intense green	Easily opened	Totally green and turgid	No appearance of symptoms
15	Slightly fresh	Regular	Green with white	Slight effort to open	Slightly green and whitish	Slight appearance of symptoms
10	Slightly fermented	Dehydrated or with the appearance of fungi	Yellowish-green	Difficult to open	Whitish-green and slight turgid	Browning
5	Very fermented	Awful	Green with brown	Strong effort to open	No turgency and limp	Strong or marked appearance of symptoms and indications of pathogens

TABLE 3. Percentage of weight loss in time intervals for the 'Santa Isabel' peas between day 0 and day 14 after the application of the wax coatings.

Treatment	0 - 3 d	3 - 5 d	5 - 7 d	7 - 10 d	10 - 12 d	12 - 14 d
Control	8.15 a	2.14 a	6.65 a	9.85 a	7.15 a	3.86 a
Cerabrix	1.86 bc	0.11 c	2.00 bc	1.64 b	1.19 d	0.98 d
Taowax	2.34 bc	0.16 c	3.14 bc	2.34 b	1.09 d	1.58 cd
Ceratec	1.45 c	0.68 bc	3.45 bc	3.92 b	1.91 cd	2.93 ab
Ceratec wwd	3.00 b	0.66 bc	3.98 b	4.06 b	4.06 b	0.99 d
Castor oil	2.48 bc	1.05 b	1.83 c	3.38 b	3.13 bc	2.39 bc
Mineral oil	2.47 bc	1.15 b	3.31 bc	4.67 b	2.21 cd	1.81 bcd
Coating mean	2.26	0.64	2.95	3.34	2.27	1.78

Means with different letters indicate significant differences according to the Tukey test ($P\leq0.05$).

decrease in the moisture of the pea samples was also seen in the control, but on a larger scale (Tab. 3).

The mean weight loss of the wax-coated peas up to 14 d was 64.96%, less than that of the control (Fig. 1), highlighting the advantage of the application of wax coatings in the conservation of accumulated water in the vegetable product. Similar results of a lower water-loss in coated vegetables were found in peppers using Sta Fresh® (Morgado *et al.*, 2008), in zucchini with Semperfresh® (Avena-Bustillos *et al.* (1994) and in the tomato with Zein (Park *et al.*, 1994), among others.

The coating that best controlled weight loss ($P\leq0.05$) was (non-edible) Cerabrix (7.78%), followed by Taowax verduras (10.65%), demonstrating the efficiency of these two products, which are modified, natural-resin solutions (Tao Química, 2007a, b) and that Taowax verduras is suitable for the preservation of peas. The other types of coatings demonstrated a higher water loss ($P\leq0.05$) that oscillated between 14.27 and 16.74%, but that were always much less than the uncoated peas with 37.79% (Fig. 1).

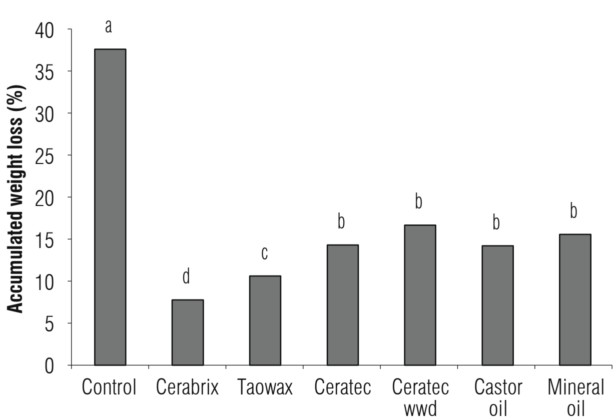

FIGURE 1. Weight loss during the 14-d-storage of 'Santa Isabel' peas in the treatments with different wax coatings, as compared to the control. Means with different letters indicate significant differences according to the Tukey test ($P\leq0.05$).

pH

The grain pH generally decreased during the 14 d of storage, with the lowest pH on 5 d occurring with the castor oil ($P\leq0.05$). For the first 10 d, differences were not observed between the treatments; however, after 10 d, the peas coated with Ceratec or Ceratec wwd again increased the pH of the grains but Taowax did not, presenting the lowest pH (Fig. 2), leading to the conclusion that the chemical composition of this wax product may have influenced the grain pH in this treatment. In general, with the exception of Taowax, during the 14 d of storage, there was not much difference in the pH of the different wax treatments on any of the three determined dates, which agrees with the results of Seehanam *et al.* (2010) from a study on tangerines and six distinct commercial coatings. In addition to storage time, temperature also influences pH changes, as was demonstrated by Chiumarelli and Ferreira (2006) with observations of a significantly higher pH at 25°C as compared to 12.5°C in "Debora" tomatoes with three different waxes.

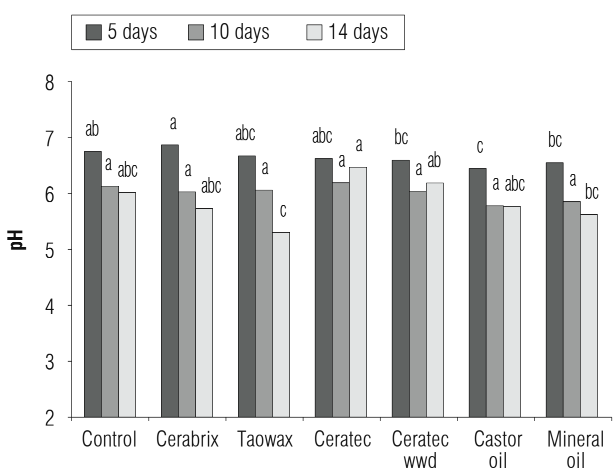

FIGURE 2. pH behavior of the peeled peas on 5, 10 and 14 d after the start of the experiment.

Organoleptic and physical characteristics

Aroma

At 5 d, half of the waxes remained “very fresh”, presenting a decrease in aroma during the storage, especially in the Ceratec wwd, castor oil and mineral oil treatments, which presented fermented odors (Tab. 4). A high preservation of the aroma was not seen, as compared to the control, with the use of wax coatings, as mentioned by Olivas *et al*. (2008). Possibly, the evaluated aroma may have been influenced by the characteristic odors of each wax: Cerabrix grees with an ammonium odor (Taoquímica, 2007a), Taowax with an alcohol odor (Taoquímica, 2007b), Ceratec with a slightly ammonium odor (Hortitec de Colombia, 2007), and castor oil with its characteristic odor (Disproalquímicos, 2007).

Appearance

Appearance was classified by Lin and Zhao (2007) as the most important attribute in minimally processed, fresh products. The appearance of the treatments at 5 and 10 d after the start of the experiment fluctuated between “excellent and regular”. On the other hand, on day 14, the majority were “dehydrated or had the appearance of fungi” and had a tendency to become “awful” (Tab. 4, Fig. 3). These characteristics resulted from the water loss, natural senescence or the growth of microorganisms (Kader, 2011; Dhall, 2013). Only the Taowax application tended to conserve a better appearance than the control at the end of the experiment, while the peas coated with Cerabrix or Ceratec maintained the same appearance as the untreated ones, results that confirm the observations of Ochoa-Reyes

TABLE 4. Scoring results for the organoleptic and physical characteristics.

Treatments	Aroma			Appearance			Pod color			Pod opening			Grain maturity		
	Day			Day			Day			Day			Day		
	5	10	14	5	10	14	5	10	14	5	10	14	5	10	14
Control	20	15	10	20	15	10	15	12.5	10	15	15	15	17.5	15	10
Cerabrix	15	15	10	15	15	10	15	15	10	15	10	10	15	15	10
Taowax	15	15	10	15	15	11.3	15	15	10	15	15	10	15	15	5
Ceratec	20	15	10	20	15	10	20	15	7.5	20	15	15	20	15	10
Ceratec wwd	20	15	7.5	20	15	7.5	15	12.5	7.5	15	15	12.5	15	10	7.5
Castor oil	15	15	5	15	12.5	7.5	20	10	10	20	15	11.3	15	15	10
Mineral oil	20	12.5	6.3	20	12.5	6.3	20	10	7.5	20	10	10	15	10	5

FIGURE 3. General appearance of the treatments 7 d after the beginning of the experiment.

et al. (2013) for green peppers coated with three different biopolymers that maintained a similar appearance as the uncoated ones.

Pod color

At 5 d, the pod color fluctuated between an intense green and green with white (Tab. 4, Fig. 3); however, the pea, as a minimum quality requirement, must have a typical color of the species and variety, which, in varieties with an edible pod, is bright green (Ligarreto, 2012). In the first evaluation, the peas coated with Ceratec, castor oil or mineral oil demonstrated a better coloration than the control; however, at 10 d, this observation was made for the Cerabrix and Taowax coatings and, in the end (14 d), the products that demonstrated an intense green at the start, such as Ceratec and mineral oil, demonstrated a worse coloration than the control (yellowish-green) (Tab. 4). Yellowing of the tissue is a normal process during the senescence of the plant product; however, consumers prefer products that have an intense green color (Aydin *et al*., 2002; Artes and Gómez, 2003), indicating freshness.

Pod opening

The texture, which in this study mainly indicated the ease with which the pods were opened, in the first 5 d was found to be between “easily opened” and “slight effort to open” (Tab. 4), which, in general terms, is desirable. At 10 d after the start of the experiment, this characteristic, in the majority of the treatments, remained as “slight effort to open”. At 14 d, in the majority of the coatings, the pods were difficult to open; only Ceratec maintained the characteristic of “slight effort to open” and, in general, this product facilitated the best opening of the pods throughout the postharvest phase.

Grain maturity

In the treatments, including the control, maturity advanced during the 14 d (Tab. 4). The Taowax and Ceratec wwd coatings and especially the mineral oil coating presented a more advanced maturity than the control (Tab. 4); that is to say, the wax products were not sufficiently effective at decreasing the maturation process of the peas. Lin and Zhao (2007) and Dhall (2013) indicated that a postponement of senescence of a plant product is one of the more important requirements of a wax coatings.

Appearance of pathogens

At 5 d of the experiment, the tendency for all of the treatments was “no appearance of symptoms”. At 10 d, there was a fluctuation between “slight appearance of symptoms” and “appearance of withering” (Fig. 3 and 4). At 14 d, Cerabrix grees and Taowax verduras were the only ones to present “slight appearance of symptoms”, making the Taowax coating the more efficient one for the sanitary protection of the pea pods under the conditions of this study. Since coatings can be seen as a type of modified atmosphere (Orjuela-Baquero *et al*., 2014), an increase in the concentration of carbon dioxide and decrease in oxygen can have a direct effect on postharvest diseases because fungal pathogens require O_2 just like fruits; this change in the concentration of the two gases inevitably decreases the growth of pathogens (Adaskaveg *et al*., 2002).

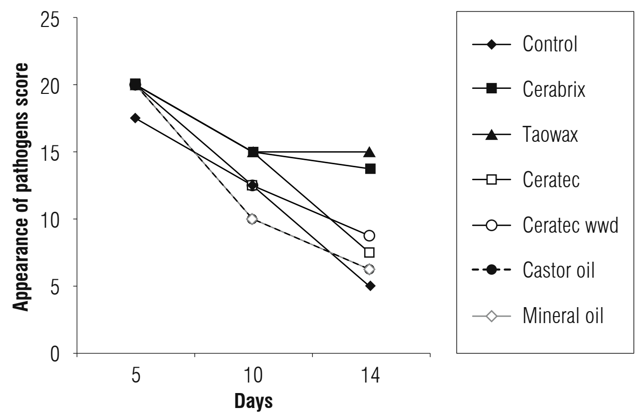

FIGURE 4. Pathogen appearance behavior at 5, 10, and 14 d after the start of the experiment.

Conclusions

All of the wax coatings protected the pea fruits from water loss. The pH had a acidic tendency during the storage, probably due to the incidence of the wax coatings and the maturity of the peas. Both the physicochemical and the organoleptic characteristics were dependent on the postharvest time. The non-edible Cerabrix grees and the edible Taowax verduras coatings demonstrated good results in terms of lower weight loss and fewer pathogenic symptoms, and the latter also presented a good aroma, appearance and color.

Acknowledgements

The authors wish to thank the companies Taoquímica Ltda., Disproalquímicos S.A., Químicos y Cápsulas Ltda. and Hortitec de Colombia S.A for their contributions and for allowing the evaluations of the wax coatings. The authors are grateful to the Scheelea Group S.A.S farm and also to G. Fischer for revising the text.

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IN MEMORY OF JORGE HUMBERTO ZURITA VANEGAS

Jorge Humberto Zurita Vanegas (R.I.P.) was born in Bogota on November 10, 1959. From 1978 to 1986, he studied Agronomy at the Universidad Nacional de Colombia, Bogota. Between 1989 and 1992, he completed his Master's degree in Agricultural Sciences at the University of Hohenheim, Stuttgart (Germany), with a specialization in horticulture and postharvest. After gaining more than 10 years of experience in the private sector, in 2001, he joined the teaching staff of the Facultad de Agronomia at the Universidad Nacional de Colombia, Bogota, where he worked as a professor in the fields of plant physiology, horticulture, postharvest and food quality. His teachings gave emphasis to the application of agronomic knowledge for the improvement and development of the agricultural sector. He always counseled his students on the importance of self-improvement, as well as social progress, in the pursuit of a life balanced between work and family.

Juan Carlos Barrientos