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Incorporation of Electromagnetic Fields as an Alternative Technology to Increase Starch Production in Corn Crops

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During the last decades, the production of fuels derived from agricultural products called agrofuels or biofuels has been promoted as an alternative to high oil prices and pollution due to carbon dioxide emanating from the primary sources found for that purpose. In this sense, corn is part of the cereals most used in the production of bioenergy, likewise, it is recognized as the most productive vegetable species since antiquity. In the previous context, this project evaluated the performance of starch, as well as the physical-chemical characteristics of corn grains that were subjected to electromagnetic fields. For this, the content of protein, fiber, fiber in acidic detergent, fiber in neutral detergent, fat and nitrogen was determined by official methods 08-01, 46-13 and 30-25 of the AACC. Alike, by optical microscopy, the starch granule was morphologically characterized, with an Accu-scope 3000-led-40 optical microscope with a digital camera Aptina CMOS Sensor of 14 megapixels. For the microscopic observation, suspensions of starch in excess of water were prepared, taking them to a slide, after, covered by cover-object and observed at 100, 400 and 1000 times. The starch yield was determined gravimetrically with soaking in ethyl ether and washing in 96 % ethanol in 40, 100 and 200 U.S. sieves to collect the precipitated starch eliminating the excess of the reagent by evaporation at room temperature. The field and laboratory experiments were carried out at the Fundación Universitaria Agraria de Colombia – UNIAGRARIA, with Porva corn, harvesting until the grain matured (168 days after sowing). For this, it was taken into account that the seeds, before sowing, had been treated with electromagnetic fields at intensities of L1-23 µT, L2-70 µT and L3-118 µT; Electromagnetic field intensities or flux density (in microtesla, µT) were created artificially from the interconnection of electronic devices that carry electrical charges that act as energy sources; moreover, it was observed that with the application this force, the recovery (yield) in the starch doubled without affecting the characteristics of the compound. Finally, the statistical analyzes were performed in the statistical package Statgraphics 5.1Plus, developing a simple variance analysis and a multiple range test.

1. Introduction

Starting from the premise of the weakening of the earth's magnetic field and the consequences that this brings on the physiological processes that naturally develop in living beings in general and in particular in plants, it is necessary to reestablish this artificially (Carbonell, Flórez, Martínez and Álvarez, 2017). This process can be carried out using electromagnetic fields induced at low intensity, so that the cells can express, at least in theory, all their biological potential, either by cellular repolarization or chromosomal stimulation (Torres, Díaz and Cabal, 2008). Thereby, for a small, medium or large producer, having quality botanical seeds has always been a determining factor when expecting good agricultural yields (Hincapie, Torres Osorio and Bueno López, 2010).
Obviously, it cannot be ruled out that the decrease in the germination power of the botanical seed, which sometimes occurs, may be associated with different factors of the product and the surrounding environment, among which there is a bad post-harvest handling (Ortega- Martínez, Sánchez -Olarte, Díaz-Ruiz and Ocampo-

Mendoza, 2010). Such, the search for methods or technologies that improve the quality of botanical seed is urgent, which becomes a vitally important challenge considering that this type of biological material is prone to loss of vigor and viability during Prolonged storage.
The previous statement, so, forces us to look for tools or techniques that allow to stimulate seed embryos with low viability and thus increase both productivity and quality in crops of economic interest, despite the exogenous factors that limit their development (Quintana- Blanco, Pinzón-Sandoval and Torres, 2016).

2. Material and methods

2.1 **Characteristics of vegetable material**

The study was conducted in the Natural Ingredients laboratory and the raw material came from tests carried out in the experimental plots of the Fundación Universitaria Agraria de Colombia - UNIAGRARIA. It is located at 170 No 54A -10, Bogotá DC (Colombia), with coordinates 4°45´70´´N and 74°03´12´´O, at an elevation of 2650 m above sea level, with a relative humidity of 94% and an average annual temperature of 14 °C. For the establishment of the crop that gives rise to the raw material, certified commercial corn seeds (Zea mays L. var Porva) were used since this is the main variety grown in the Sabana de Bogotá. It should be noted that the plants that originated the fruits under study (the seeds that were sown) were subjected to stimuli with electromagnetic fields of low intensity prior to planting (23, 70 and 118 µT) that were generated by electronic circuits in the chamber of electromagnetic stimulation.

2.2 Preparation of sample

This step was carried out with the purpose of enlisting the raw samples or at a significant particle size for the development of each of the analyzes that were executed, as well as the standardization of samples. Then, the accommodation of the raw material was placed in Ziploc packages properly labeled in a desiccator to regulate the moisture content.

During the sample preparation and storage processes, it was specified that these did not show changes in constitution, that is, by regulating the working conditions (asepsis), some kind of contamination, mixing of samples or loss of heavy material was avoided.

2.3 Proximal analysis

In the laboratory one (1) specimen of each sampling unit is prepared for future analysis. Thus, the raw protein (Method 46-13, AACC 2000), moisture (method 925.10, AOAC 2000), total dry extract or fat (Method 30-25, AACC 2000), insoluble dietary fiber, fiber was evaluated for corn soluble dietary and total dietary fiber (method 992.16, AOAC 2000). All measurements were carried out in triplicate (AACC, 2000; AOAC, 2000).

2.4 Starch yield

The method proposed by Agama-Acevedo et al. (2011) with modifications. The corn grain (true fruit) was manually removed pericarp, pedicel and germ, to obtain the endosperm, which was ground in a commercial mill (IKA - WERKE M-20) and screened in meshes of40, 100 and 200 U. S., 114 g were weighed, 500 ml of ethyl ether was added and allowed to stand for 24 h. Subsequently, the ether was removed by decantation and the wet flour was milled in 1 L of 96% ethanol and then sifted the suspension in the aforementioned amices. The residues of each sieve were washed with enough 96% ethanol to recover as much starch as possible. The starch was allowed to decant, and the ethanol was removed, for then dried in aluminum trays. The powder obtained was stored in glass jars. The starch yield was determined as expressed in equation 1.

$$Starch\ yield\ (\%) = \frac{Rs*100}{RMW} \quad (1)$$

Where:

Rs = Recovered starch
RMW = Raw Material Weight

2.5 Starch granule morphology

The morphological analysis of the corn starch granules was carried out by means of optical microscopy (ACCU-Range 3000-Led 40 optical microscope) with the Aptina CMOS digital camera coupling of 14 megapixels. Samples (0.5) grams were prepared by suspension in excess of distilled water to be immediately taken to the slide and then covered and observed under the light microscope (Londoño 2014).

2.6 Treatments and statistical analysis

The evaluations were carried out in triplicate for each of the treatments, as evidenced in studies carried out by Suárez-Rivero et al. (2018). The treatments correspond to:

L1_ treated plant grains to 23 µT
L2_ treated plant grains to 70 µT
L3_ treated plant grains to 118 µT
CP_ control plant grains

From the statistical point of view, an analysis of variance (ANOVA) was performed between the average of the samples per treatment with a significance level of 95% (± = 0.05) to establish if there are significant differences, as well as a range test multiple to establish the level of significance (Suárez, 2011). Both tests were performed with Statgraphics 5.1 PLUS statistical software.

3. Results and discussion

3.1 Proximal analysis

The variations found during the proximal analysis of the raw material are represented in three figures. For its part, Figure 1 comparatively reflects the average moisture content of the treatments compared to the control, this figure shows significant statistical differences between the control (54.03%) and the rest of the treatments (L1 = 32.6%, L3 = 32.24%, L2 = 34.01%), which do not differ from each other. Everything seems to indicate that there is an incidence on the moisture content through electromagnetic induction and may be additionally related to an advance in the ripening of the fruits and therefore reduction of the humidity of the caryopsides and that it could limit the shelf life of the product.

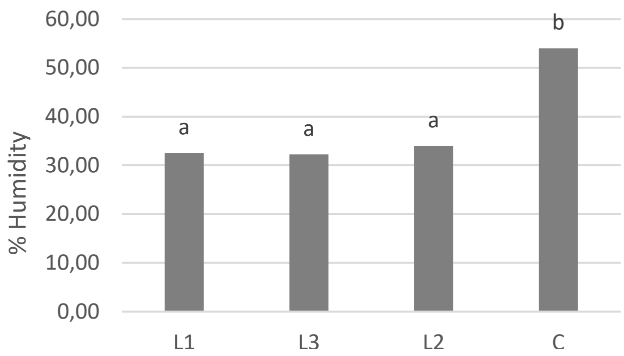

Figure 1: Moisture percentage content of plant material according to treatment (Equal letters show no significant differences between treatments and different letters show significant differences between treatments (p= 0.05)).

The previous analysis indicated the amount of water that a raw material contains, which allowed to infer to a certain extent the quality of it, because depending on the humidity that it possesses it is easier to conserve and have less probability of contamination (Suarez et al. 2016).
Thus, in accordance with the results obtained for the moisture content, the nitrogen and protein content shown in Figure 2 reflects the highest values for the Control raw material (% Nitrogen of 0.23 and% of Protein 1, 46), differing significantly from treatments (L1 to L3); inferring that it could be related to the level of ripening of the fruit, since immature fruits contain relatively high levels of sugars and lower amounts of starch, protein and lipids, since these accumulate during ripening, as stated in studies by Álzate-Carvajal et al. (2013).

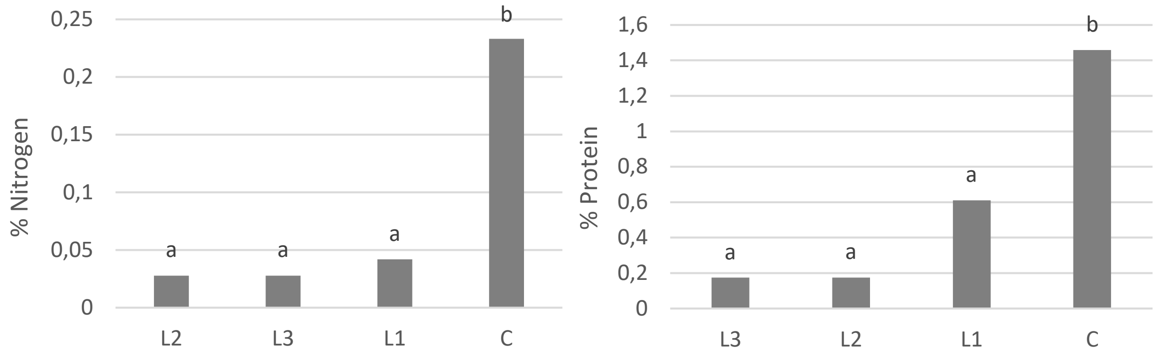

Figure 2: Percent nitrogen and protein content of plant material according to treatment (Equal letters show no significant differences between treatments and different letters show significant differences between treatments (p= 0.05)).

On the other hand, during the determination of fat (Ethereal Extract), the little lipid fraction present in the corn kernel was linked to the petroleum benzine (C_6H_6) thanks to its lipophilic action. By means of the volatilization of the solvent, it was condensed and descended on the sample, in order to extract the fat present; in this sense, the L2 treatment, according to figure 3, showed the highest levels of fat (8.03%), differing significantly from the rest of treatments and control.

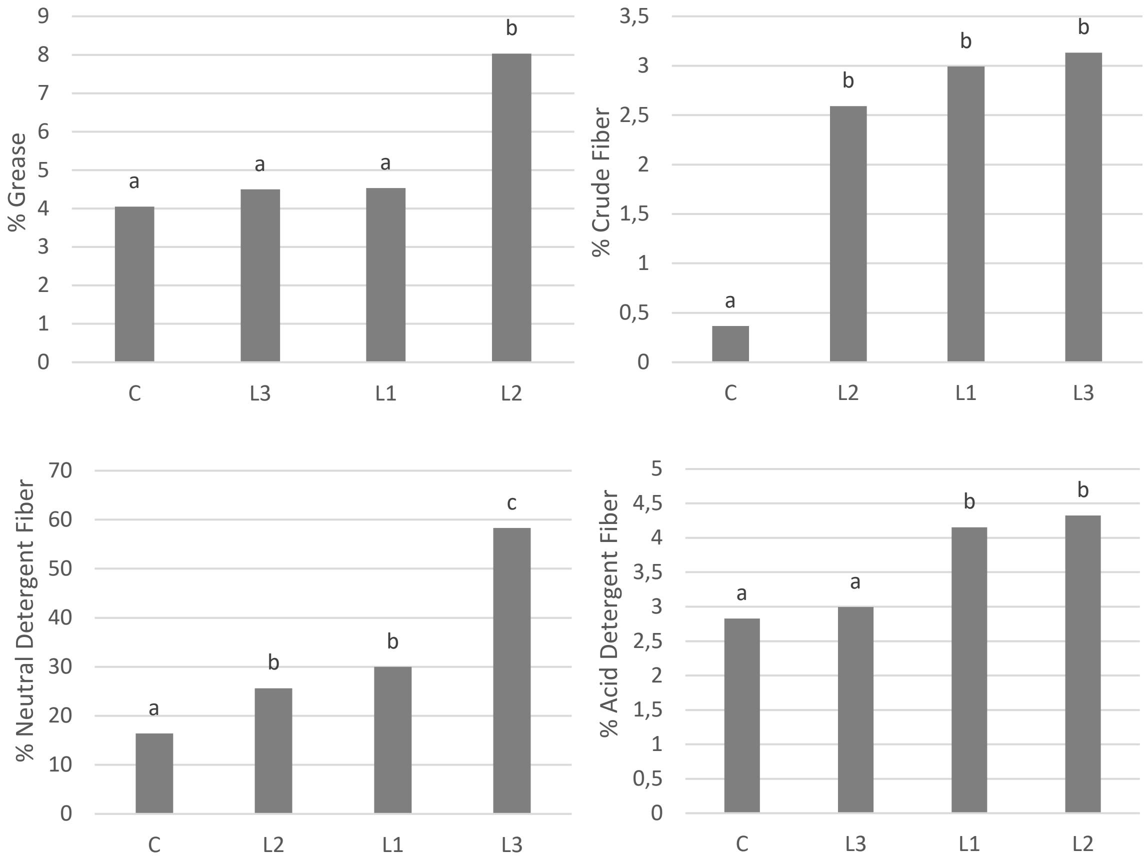

Figure 3: Percentage content of fat and fibers (FC, NDF, ADF) according to plant material components according to treatment (Equal letters show no significant differences between treatments and different letters show significant differences between treatments (p= 0.05)).

Moreover, when analysing the fiber content (FC, NDF, ADF) in Figure 3, the tendency to present higher values in fruits from plants treated with electromagnetic fields is observed. It is noteworthy that between the treatments L1 to L3 there were no significant differences for the Crude Fiber content, existing some differences for NDF and ADF; in the NDF content, L3 stood out with 58.32% and for the ADF indicator L2 and L1 with 4.33 and

4.15% respectively. Then, the results obtained allow assume that after processes such as dehydration of the fruits, a concentration of nutrients is produced that makes the values of fiber and other nutrients greater and show variations, as detected by Uarrota et al. (2013) in similar studies.

3.2 Starch yield

To refer to the starch yield, it is necessary to note that the granules formed are stored in the seed's endosperm (Colorado et al., 2019) in cellular organelles called amyloplasts (active plastids), representing approximately in full, an 87, 6% of the total dry weight of this, except that, the recovery percentage is always much lower (Uriarte-Aceves, 2015). In consonance with the above, Figure 4 reflects the higher content of starch recovered for the caryopsides of plants that were treated with electromagnetic fields, reaching 41.38% in L3, which does not differ significantly from L1 and L2, which showed yields of 35.69 and 33.34 respectively.

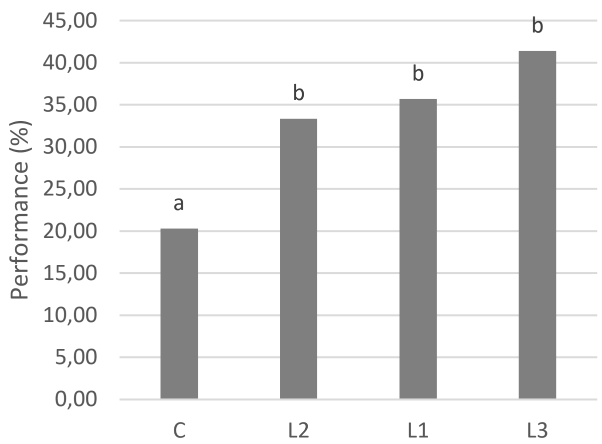

Figure 4: Starch yield of plant material according to treatment (Equal letters show no significant differences between treatments and different letters show significant differences between treatments (p= 0.05)).

3.3 Starch granule morphology

Figure 5 shows the images obtained with the use of optical microscopy; the granules for all treatments and control have predominantly spherical and a few irregular shapes (polygonal or polyhedral, conical, angular). In general, granules of various sizes were found in the analyzed samples (5-20 µm), with the larger ones predominant, regardless of the treatment or control. It is noteworthy that numerous properties of the starches are directly related to the size of the granule, for example, the chemical composition, enzymatic susceptibility, gelatinization crystallinity, paste formation, swelling and solubility properties (Lindeboom et al., 2004).

Figure 5: Morphology of starch grains according to treatments (images taken at 1000 magnifications) with starch grain sizes between 8.4 and 12.3 µm.

Delpeuch and Favier (1980) cited by Álzate Carvajal et al. (2013) indicate that, in addition to the above, the size of the starch granule is decisive in its functional properties, the smaller the granules, the greater its digestibility and the greater its resistance to high temperatures in processes such as sterilization, also determining the amylose/amylopectin ratio.

4. Conclusions

The characteristics of starch grains, as reflected by the proximal analysis, show the variability of the use of electromagnetic fields in this species to increase the starch yield without affecting the quality of the starch grain formed.

The analysis of the morphological characteristics of the starch granules of the three treatments and the control showed similarities regarding the shape, size and distribution of granules. That is how, the texture of starch grains becomes a fundamental feature related to some characteristics of their industrial quality (such as density), agronomic (such as susceptibility to attack by pests and diseases during storage); further, of nutritional (such as its susceptibility to enzymatic hydrolysis during digestive processes).

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