Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

INIFAP-NATIONAL MANGO BOARD AGREEMENT

QUALITY AND SHELF LIFE OF TOMMY ATKINS MANGO SIZE 12's AND ATAULFO SIZE 20-22 PACKED IN BREATHABLE BAGS

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INDEX

EXECUTIVE SUMMARY

In the last two seasons (perhaps due to agroclimatic conditions and restrictions of residual humidity in the soil), small sizes have increased their percentage, reaching up to 23% of the total exported. The most critical situation occurs in ‘Tommy Atkins’ with up to 21% of sizes 12’s and in ‘Ataulfo’ with up to 23% of sizes 22’s. What appears to be a disadvantage, it may turn into an opportunity since market trends have been changing and marketing small fruits in bags containing 4 to 6 fruits could increase consumption.

Therefore, during 2020 an experimental trial was established in Mexico and a validation in Ecuador with the purpose of investigating the effect of packaging on the quality and shelf life of ‘Ataulfo’ and ‘Tommy Atkins’ mango fruit. For this, four treatments were tested: 1. Edi Mesh, 2. Combo Mesh, 3. Fresh Mesh and 4. Control, with a size of 22 count (average weight of 182 g) in 'Ataulfo' and 12 count (average weight of 333 g) in 'Tommy Atkins'. After the 75 min Quarantine Hydrothermic Treatment without hydrocooling, fruit of the aforementioned sizes were selected for each variety, which looked ripe, with excellent external appearance and free of mechanical damage, pests and / or diseases. Subsequently, fruit were packed in each bag with their respective control. For fruit grown in Mexico of 'Ataulfo' variety, 6 fruits were placed per bag and 8 bags for each 5 base box, as well as the bulk control with 53 fruit per box, while for 'Tommy Atkins' 4 fruit per bag and 6 bags for each 5 base box, and the control with 32 fruit in bulk. Once the treatments were prepared, they were placed in a conventional cold room for three weeks at 53.6 ± 1.5 °F; 85 ± 10% RH, simulating transport in a refrigerated container from South America to the United States. At the end of the refrigerated shipping simulation, the fruit was transferred to a marketing simulation (71.6 ± 3.0 °F; 75 ± 10% RH) until reaching maturity for consumption. The variables analyzed were: dry matter, weight loss, external appearance, peel color, firmness, pulp color, content of total soluble solids, acidity and °Bx/Acidity ratio; A completely randomized design was used, with 20 replications for weight loss and 10 for the rest of the variables.

For the validation in Ecuador, fruit of the referred sizes were used and selected in a similar way to the experimental trial, but here 7 boxes 5 base per treatment were formed; in ‘Ataulfo’ each box contained 8 bags with 6 fruit for each treatment and the control without bag with 53 fruit in bulk. Similarly, for 'Tommy Atkins' 7 boxes were formed, each containing 6 bags with 4 fruit for each treatment and the control without bag with 32 fruit in bulk. Of the 7 boxes, 3 were kept for analysis in the packinghouse ('Ataulfo' fruit was processed in Bresson packinghouse and 'Tommy Atkins' fruit in Pivano packinghouse) and 4 were sent via refrigerated marine container to Florida where they were evaluated at the end of the shipment and at consumption, supported by the broker and by personnel from the National Mango Board (NMB). The variables analyzed by the packers were weight loss, external appearance, firmness, pulp color and total soluble solids, while in Florida the same variables were evaluated except for weight loss. A completely randomized design was used combining the data obtained by the packer, broker and NMB. For weight loss, 3 replications were made for bags and 10 replications for control fruit, while the rest of the variables were evaluated with 6 replications for 'Ataulfo' and 4 replications for

'Tommy Atkins'. The variables were recorded at the beginning of the trial, at the end of three weeks of refrigeration and at consumption, both for the fruit grown in Mexico and Ecuador.

It was found that any of the bags was better than the control for most of the variables, both in the fruit grown in Mexico and in Ecuador, highlighting the Mesh Combo bag, which decreased weight loss and increased the °Bx/Acidity ratio in both varieties compared to the control fruit.

The trial was scheduled to be repeated during the 2021 season considering the best treatment, the Mesh combo bag + the control and two more environmentally friendly recycled cardboard alternatives. Unfortunately, the trial was not carried out because the supplier was unable to provide the NMB with the two-cardboard packages.

BACKGROUND

The United States imports mango from Brazil, Peru, Ecuador, Haiti, Guatemala and Mexico with an approximate volume of 120 million boxes. The main exporter is Mexico with 65.6% of the volume traded (USDA Foreign Agricultural Service, 2018). The main varieties exported are Tommy Atkins, Ataulfo, Haden, Kent and Keitt. In the last two seasons (perhaps due to agroclimatic conditions and restrictions of residual humidity in the soil), small sizes have increased their percentage, reaching up to 23% of the total exported. The most critical situation occurs in 'Tommy Atkins' with up to 21% of sizes 12's and in 'Ataulfo' with up to 23% of sizes 22's (NMB, 2019). However, what appears to be a disadvantage has become an opportunity as market trends have been changing. Due in large part to the National Mango Board's (NMB) promotion program, per capita consumption has almost doubled from 1.7 Lbs in 2000 to 3.16 Lbs in 2018 (USDA, Economic Research Service, 2018). Twenty two percent of consumers report having bought mango at least once during the year. Ethnic groups that consume the most mango are Asians and Hispanics and the regions with the highest mango consumption in the USA are the West (28%), the Northeast (26%), the South (20%) and the Northwest (18%), while 78% of purchases were made by people between 18 and 58 years old (Mangoes_freshtrends, 2018). On the other hand, the average number of mango purchased per household during 2008 to 2013 remained around 2.73 and in the period from 2014 to 2018, it increased to 3.4 fruit / household (Ward, 2014; 2018). It is therefore an opportunity to promote another change in the market, since at present the mango is traded in cardboard boxes of 35, 14, 10 or 8.8 Lbs. In other fruit such as apples, oranges, limes or avocados, it has recently become popular to market the smallest fruit in plastic bags combined with colored meshes (similar to the fruit they contain). These colored bags allow some gas exchange to let entry oxygen and CO_2 output because of breathing, which, in addition to extending shelf life, makes the fruit more attractive to the consumer (Fox Packaging, 2018). Studies carried out by the Michigan State University (Bix et al., 2013) regarding the Consumer's reaction to the mesh color, they stated that mesh color impacts on the purchase intention and perception of quality of the fruit to be acquired. When the mesh color of the bag is similar to that

of the fruit, both, the purchase intention and the quality perception are increased. In addition, there are many other benefits of this type of packaging: a) Decreased wilt and waste, b) Longer shelf life, c) Product more attractive to the consumer, d) Safety, e) Decreased costs, f) Differentiation of brand, and g) Sustainability, among others (Fox Packaging, 2018). In fact, the company Diazteca from Mexico has already experimented with Fox Fresh Combo 5.5 Lb bags (Figure 1), while Costco markets Ataulfo mango in plastic containers with a capacity of six fruits and 3.3 Lb (Figure 2).

Figure 1. 'Kent' mango packed in breathable plastic bags.

Figure 2. Ataulfo mangos packed in 6-piece plastic containers

OBJECTIVES

- To investigate the effect of packaging on quality and shelf life of 'Ataulfo' and 'Tommy Atkins' mango fruit.

- To determine the economic feasibility of packaging.

HYPOTHESIS

- Breathable bags and plastic containers maintain quality and extend shelf life of mango fruit at affordable and profitable prices.

METHODOLOGY

FRUIT GROWN IN MEXICO

- **Variety**: 'Ataulfo', harvested in Ixtapa de la Concepción, Compostela, Nayarit; while 'Tommy Atkins' fruit were obtained from the community of Sauta, Santiago Ixcuintla, Nayarit.

- **Place of conducting tests**: INIFAP - Santiago Ixcuintla Experimental Station, Nayarit. Postharvest and Food Safety Lab.

- **Execution Date:** 2020 Season.

- **Treatments:**

Treat	Packing type	Number of fruits*	Bag size (Lbs)	Days of refrigerated shipping simulation
1	Edi Net	6 A, 4 T	3.3 Lbs	21
2	Combo Mesh	6 A, 4 T	3.3 Lbs	21
3	Fresh Mesh	6 A, 4 T	3.3 Lbs	21
4	Control	53 A, 32 T	12.3-11.6 Lbs	21

Note: A = Ataulfo, T = Tommy Atkins; * 5 base box

- **Fruit selection:** For 'Ataulfo' fruit sized 22 count was selected (average weight of 182 g), while for ´Tommy Atkins' the fruit size was 12 count (average weight of 333 g). In both varieties, ripened fruit were chosen (rounded shape with filling of cheeks and raised shoulders, with pulp color of 2 to 3 from the EMEX chart, and a content of total soluble solids > 7.5 °Bx), with excellent external appearance, free from mechanical damage, pests and / or diseases and subjected to the hydrothermic quarantine treatment of 75 min, without hydrocooling. Fruit were packed in different containers supplied by the National Mango Board, using three 5 base boxes for each treatment and variety. Subsequently, the fruit were palletized and placed in a conventional cold room for three weeks (53.6 ± 1.5 °F; 85 ± 10% RH) for shipping simulation in a refrigerated container from South America to the United States and subsequent marketing simulation (71.6 ± 3.0 °F; 75 ± 10% RH) until consumption stage. The samplings were carried out at the beginning, at the end of the refrigerated shipping simulation, and at consumption stage.

- **Evaluated variables**:

  - **Dry matter.** By means of microwave oven according to Brecht et al. (2011). Five grams of pulp obtained with a peeler and placed in Petri dishes were dried for 4 to 7 min until obtaining constant weight. The values were expressed as a percentage.
  - **Weight loss.** By means of a digital analytical scale with an approximation of 0.1 grams. Twenty fruits were periodically weighed from the beginning to the end of the experiment. The difference in weight with respect to the initial weight was expressed as a percentage of weight loss.
  - **External appearance:** Based on a visual scale where 0 = excellent (fruit free of damage and with excellent presentation); 1 = good (fruit with good presentation, with slight defects in shape and minimal damage to the peel); 2 = fair (fruit with good presentation, with moderate defects in shape and

minimal skin damage) and 3 = poor (fruit with good presentation, but with severe skin damage). Desirable values for export are between 0 and 1.

- **Skin color.** Using the Konica Minolta CR-400 portable colorimeter, using illuminant C and reporting the 'a' value from L a b mode.
- **Firmness.** The data was taken with a Chatillon Model DFE-050 penetrometer (Ametek Instruments, Largo, FL), adapted with an 8 mm diameter cylindrical punch and expressed in Pounds force (Lbf).
- **Pulp color.** Using Konica Minolta CR-400 portable colorimeter, using illuminant C and reporting the hue angle (hue).
- **Total soluble solids (TSS).** Using a digital refractometer with temperature compensator ATAGO model PAL-1 calibrated with distilled water (AOAC, 1990).

We used a completely randomized design with 20 replications for weight loss and 10 replications for the rest of fruit variables.

FRUIT GROWN IN ECUADOR

- **Variety**: Fruit of the 'Ataulfo' variety was obtained from the Bresson packinghouse; while the fruit of 'Tommy Atkins' variety was obtained from the Pivano packinghouse, both packinghouses located in Ecuador.

- **Place of conducting tests**: In Guayaquil, Ecuador and in Miami, Florida, USA. The varieties were analyzed by the packinghouses, the Broker and the National Mango Board personnel.

- **Execution date:** From November to December 2020.

- **Treatments:**

Treat	Packing type	Number of fruits*	Bag size (Lbs)	Days of refrigerated shipping simulation
1	Edi Net	6 A, 4 T	3.3 Lbs	21
2	Combo Mesh	6 A, 4 T	3.3 Lbs	21
3	Fresh Mesh	6 A, 4 T	3.3 Lbs	21
4	Control	53 A, 32 T	12.3-11.6 Lbs	21

Note: A = Ataulfo, T = Tommy Atkins; * 5 base box

- **Fruit selection:** For the validation in Ecuador, fruit of the referred sizes were selected in a similar way to the experimental trial, but here seven boxes (5 base) were formed for each treatment; in ‘Ataulfo’ each box contained 8 bags with 6 fruits for each treatment and the control with 53 fruits in bulk. Similarly, for ‘Tommy Atkins’ 7 boxes were formed, each containing 6 bags with 4 fruits for each treatment and the control with 32 fruits in bulk. Of the seven boxes, 3 were kept for analysis in the packinghouse (fruit of 'Ataulfo' was processed in Bresson packinghouse while 'Tommy Atkins' in the Pivano packinghouse) and 4 were sent via refrigerated sea container to Florida where they were evaluated at the end of the shipment and at consumption, supported by the broker and by personnel of the National Mango Board (NMB). The variables analyzed by packers were weight loss, external appearance, firmness, pulp color and total soluble solids, while in Florida all variables were evaluated except weight loss. A completely randomized design was used combining the data obtained by the packer, broker and NMB. For weight loss, 3 replications were carried out for bags and 10 replications for control fruit, while the rest of the variables were evaluated with 6 replications in 'Ataulfo' and 4 replications in 'Tommy Atkins'. The variables were recorded at the beginning of the trial, at the end of three weeks of refrigeration and at consumption.

RESULTS AND DISCUSSION

FRUIT GROWN IN MEXICO

I. ATAULFO VARIETY.

Regarding to the dry matter content at the beginning of the experiment, 'Ataulfo' fruit had a range of 13.5 to 24.1% with an average of 20.4%, which agrees with that previously published by Osuna-García (2018).

Regarding to weight loss, at consumption time, the control treatment showed the greatest loss (12.3%), while the treatments with the least weight loss were the Mesh Combo (5.6%) and the Edi Mesh (6.9%), being statistically equal to each other, but below the control (Table 1) by showing a reduction of practically 50% in weight loss (Figure 3). The reason for the better performance of the Mesh Combo bag is that it consists of a plastic side and the other mesh, preventing more moisture loss than the Fresh Mesh, which is mesh on both sides.

Table 1. Weight loss (%) of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	0 a	3.4 bc	6.9 c
Mesh Combo	0 a	2.5 c	5.6 c
Fresh Mesh	0 a	4.3 b	9.5 b
Control	0 a	6.0 a	12.3 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

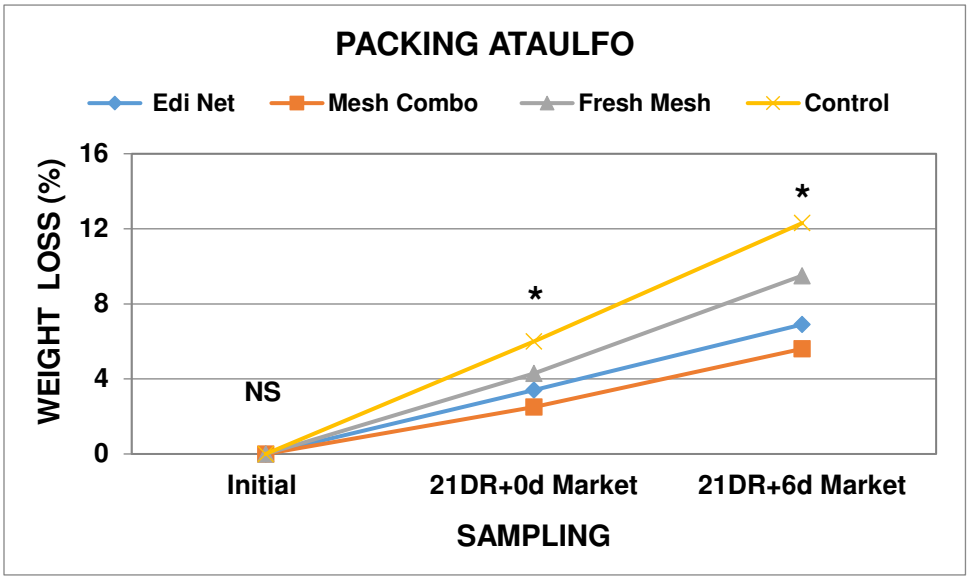


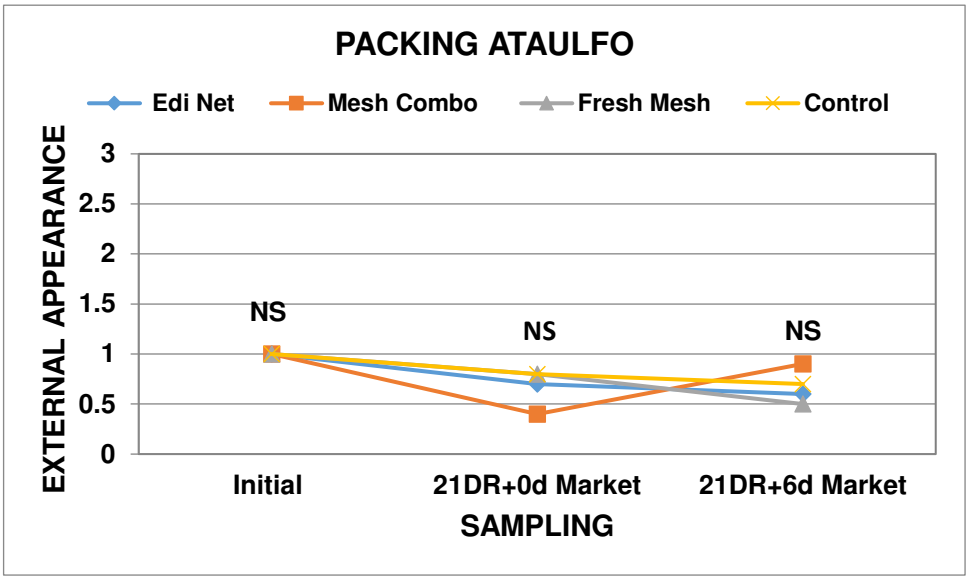
Figure 3. Weight loss (%) of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Regarding to the external appearance of 'Ataulfo' fruit packed in different bags, no statistical differences were found between treatments for any of them (Table 2). It was observed in all the samplings that the values fluctuated between 0.4 and 1.0 (Figure 4), which means that in all the samplings the fruit showed the appearance of excellent to good, desirable for export fruit.

Table 2. External appearance of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	1.0 a	0.7 a	0.6 a
Mesh Combo	1.0 a	0.4 a	0.9 a
Fresh Mesh	1.0 a	0.8 a	0.5 a
Control	1.0 a	0.8 a	0.7 a

Means with the same letter within columns are statistically equal (Duncan 0.05)



Scale 0 = Excellent 1 = Good 2 = Fair 3 = Poor

Figure 4. External appearance of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Regarding to skin color of 'Ataulfo' fruit packed in different bags; it was observed at consumption that any of the bags was better than the control. The Edi Mesh was the best (a = 13.2) with a significant difference over the Mesh combo (a = 10.3) and Fresh mesh (a = 10.9) that were statistically equal to each other, but superior to the control (a = 8.2) [Table 3]. It is worth to mention that skin color is measured with the colorimeter and ranges from negative (green color) to positive (yellow). More negative values mean intense green and more positive correspond to intense yellow. In Figure 5 can be see how the control fruit, although they started with the same green color, were turning very slowly to the characteristic yellow of the 'Ataulfo' variety. This is a very significant variable for the consumer who associates an intense yellow color with higher fruit quality.

Table 3. Skin color (a) of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	-6.4 a	7.4 a	13.2 a
Mesh Combo	-6.4 a	5.9 a	10.3 b
Fresh Mesh	-6.4 a	7.0 a	10.9 b
Control	-6.4 a	0.6 b	8.2 c

Means with the same letter within columns are statistically equal (Duncan 0.05)

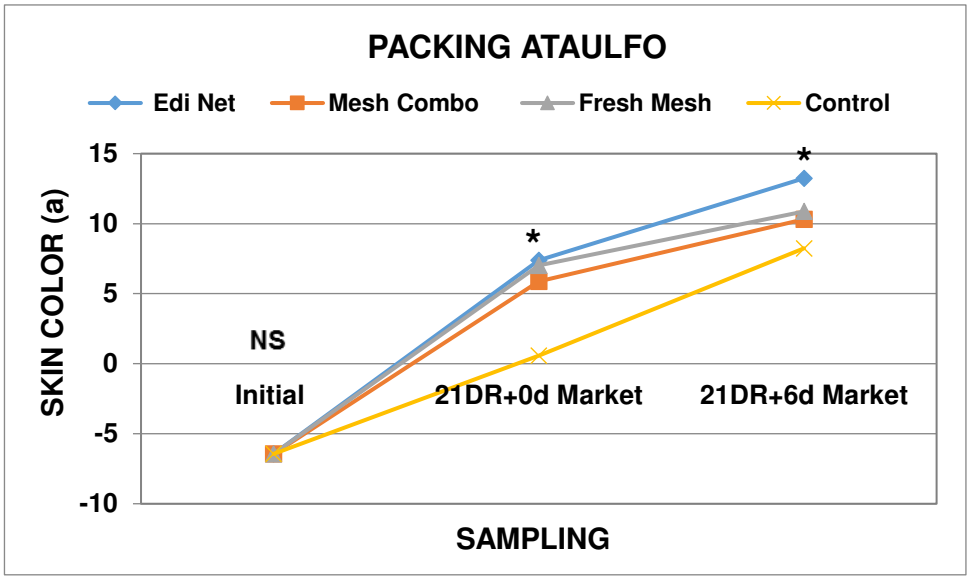


Figure 5. Skin color of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Regarding to 'Ataulfo' fruit firmness, it was observed that initial values were around 20 Lbs (Table 4) without statistical differences among treatments. It is convenient to mention that these values are relatively low because fruit were harvested very late in the season and with an advanced ripening degree. The normal values of fruit firmness are around 40 Lbs. In subsequent samplings, at the end of the refrigerated shipping simulation and at consumption, significant differences were observed

among treatments, with the control fruit showing the highest value statistically, but from a practical point of view, these differences are not biologically significant (Figure 6).

Table 4. Pulp firmness (Lbs) of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	20.6 a	4.0 b	2.2 bc
Mesh Combo	20.6 a	4.6 ab	2.2 c
Fresh Mesh	20.6 a	3.7 b	2.7 ab
Control	20.6 a	6.7 a	3.0 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

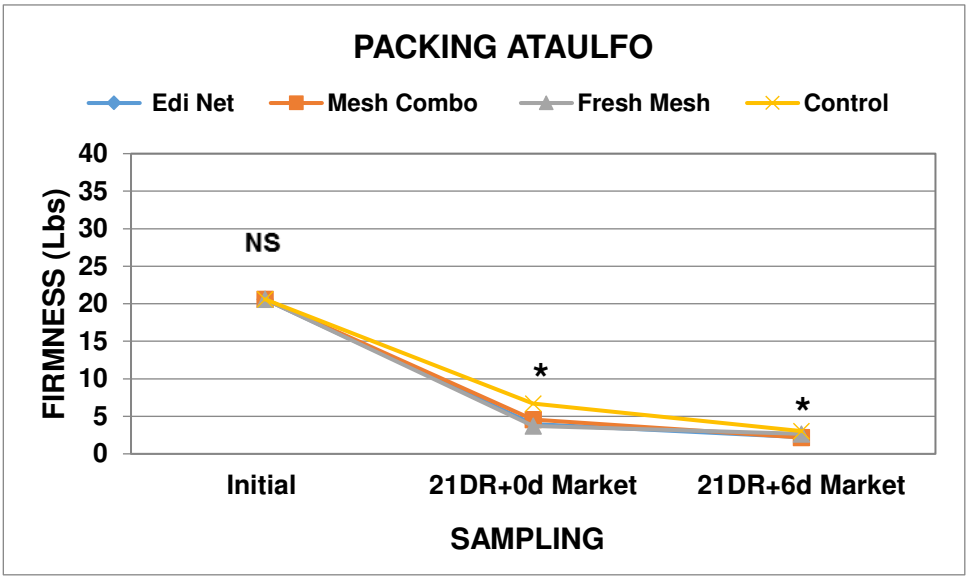


Figure 6. Pulp firmness (Lbs) of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

'Ataulfo' fruit pulp color is recorded in Table 5. No statistical differences were detected in the initial values; however, it was observed that the fruit had a maturity stage equivalent to or slightly higher than the value 3 of the EMEX table. In the two subsequent samplings, at the end of the refrigerated shipping simulation and at consumption, the fruit of any of the three bags showed a more intense pulp color than the control, which is a positive quality. Observing the trend of pulp color (Figure 7), it was confirmed that the fruit packed in the bags showed a very similar and non-significant trend among them, but higher than the control fruit. Remember that in this scale larger numbers mean less intensity of pulp color, while smaller numbers express more intense colors.

Table 5. Pulp color (Hue) of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	87.7 a	81.7 b	80.6 b
Mesh Combo	87.7 a	83.8 b	80.1 b
Fresh Mesh	87.7 a	83.4 b	81.2 b
Control	87.7 a	88.9 a	85.2 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

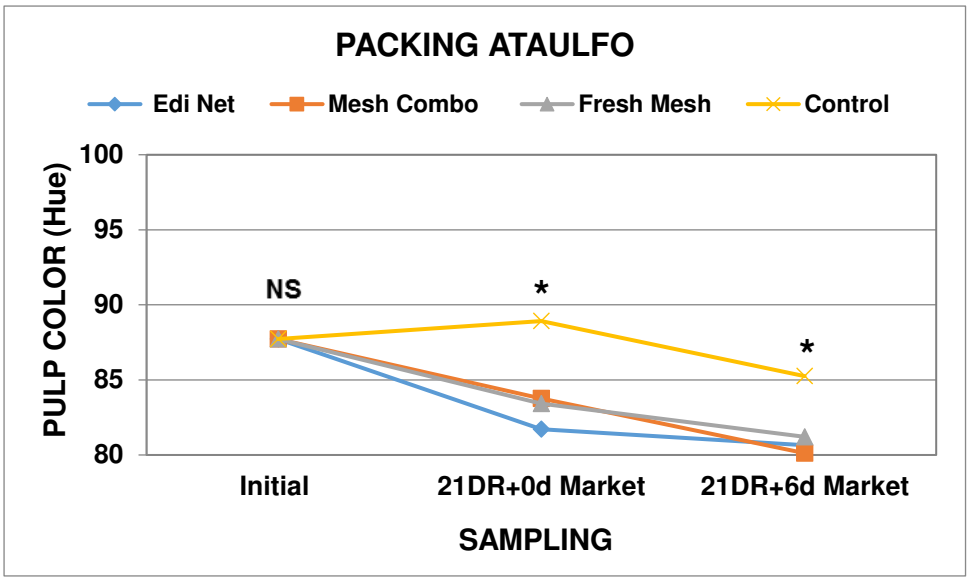


Figure 7. Pulp color (Hue) of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

A very important variable in fruit quality is the total soluble solids content (°Bx). It was observed that at consumption, any of the bags was superior to the control fruit and that the Edi mesh was the best (Table 6). Figure 8 illustrates the behavior of the total soluble solids content in the 'Ataulfo' fruit. At the end of refrigerated shipping, any of the bags were better than the control, but without differences between them, while fruit from the Edi mesh were the best at consumption.

Table 6. Total soluble solids content (°Bx) of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	8.6 a	21.3 a	22.1 a
Mesh Combo	8.6 a	19.2 a	19.3 b
Fresh Mesh	8.6 a	20.4 a	17.6 b
Control	8.6 a	15.3 b	13.8 c

Means with the same letter within columns are statistically equal (Duncan 0.05)

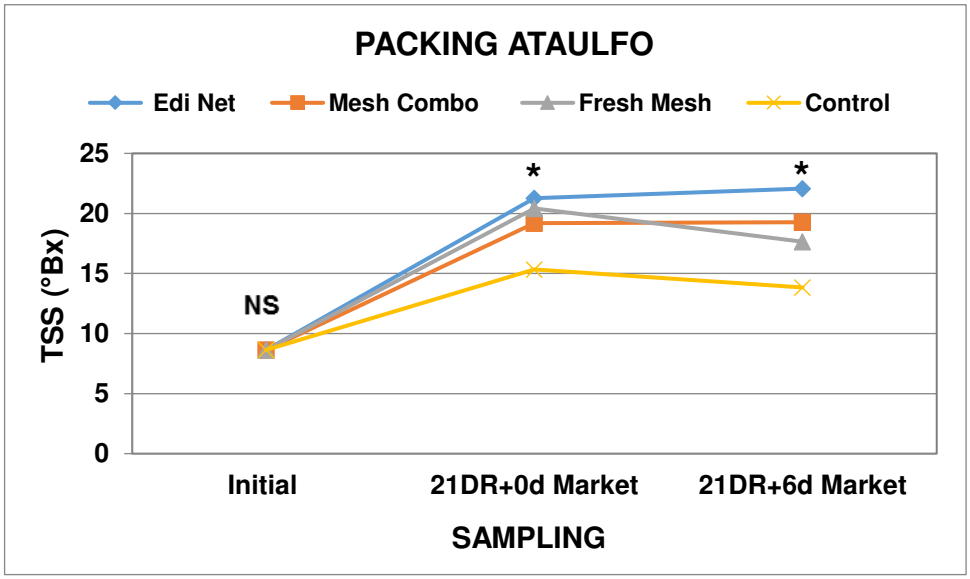


Figure 8.Total soluble solids content (°Bx) of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Regarding to the acidity of 'Ataulfo' fruit packed in different containers, at the beginning it is possible to perceive the high acidity degree of the fruit at harvest (3.4% citric acid), without detecting a significant difference among treatments (Table 7). However, both at the end of the simulation of refrigerated shipping and consumption, significant differences were detected among treatments. The control fruit showed the highest acidity at the end of the refrigerated shipping simulation, while, at consumption, the fruit packed in the Mesh combo was the best without statistically differing from those packed in the Fresh mesh (Figure 9).

Table 7. Acidity (% citric acid) of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	3.4 a	1.4 b	0.8 a
Mesh Combo	3.4 a	1.2 b	0.4 b
Fresh Mesh	3.4 a	1.5 b	0.5 b
Control	3.4 a	2.0 a	0.7 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

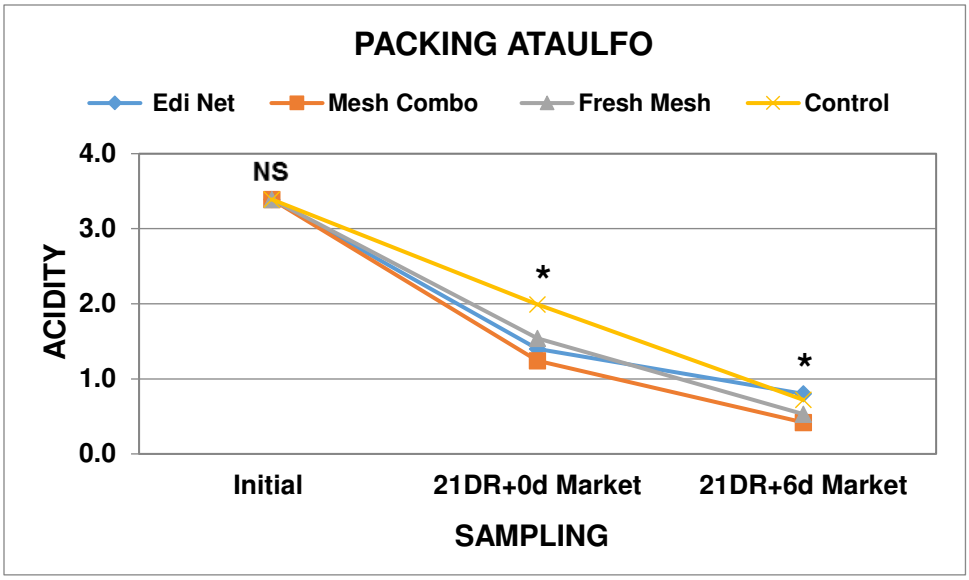


Figure 9. Acidity (% citric acid) of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Another of the variables with the greatest impact on quality for consumption is the °Bx/Acidity ratio. Statistical differences were observed among treatments. The fruit packed in the Mesh combo bag showed the best relationship, while the control fruit, the worst (Table 8). The trend of higher °Bx/Acidity ratio of any of the bags compared to the control was marked from the end of the refrigerated shipping simulation and was more evident at consumption. The fruit from the Mesh combo bag were the

highest, which indicates a higher quality by having a better sweetness/acidity balance (Figure 10).

Table 8. Ratio Bx/Acidity of 'Ataulfo' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	2.5 a	15.2 a	27.6 bc
Mesh Combo	2.5 a	15.5 a	45.9 a
Fresh Mesh	2.5 a	13.3 a	33.3 b
Control	2.5 a	7.7 b	19.2 c

Means with the same letter within columns are statistically equal (Duncan 0.05)

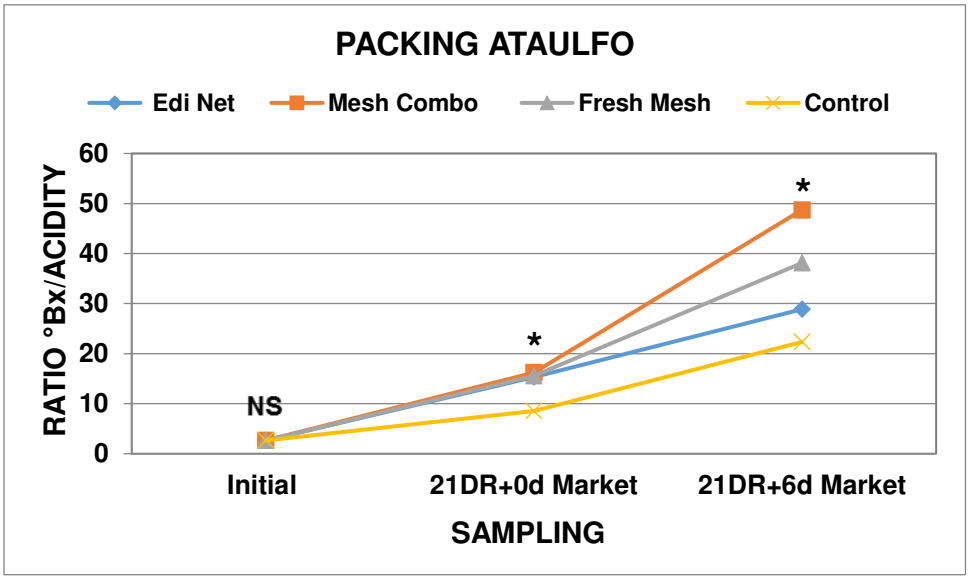


Figure 10. Ratio Bx/Acidity of 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

II. TOMMY ATKINS VARIETY.

Regarding to the dry matter content at the beginning of the experiment, 'Tommy Atkins' fruit ranged from 13.6 to 18.1% with an average 15.8%, which agrees with that previously published by Osuna-García (2018).

Regarding to weight loss at the time of consumption, the best treatment was the Mesh combo bag, which presented only 4.9% of accumulated loss, while the control, the Edi mesh and the Fresh mesh presented losses from 6.7 to 7.5% without significant differences among them (Table 9). The weight loss trend is illustrated in Figure 11. It is observed from the sampling to the end of the refrigerated shipping simulation that the best treatment was the Mesh combo bag and this trend is further extended to consumption, where those bags reduced by up to 35 % weight loss in comparison to other treatments. The reason for the better performance of the Mesh Combo bag is that it consists of a plastic side and mesh on the other, preventing more moisture loss than the Fresh Mesh which is mesh on both sides.

Table 9. Weight loss (%) of 'Tommy Atkins' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	0 a	2.0 a	7.4 a
Mesh Combo	0 a	1.4 b	4.9 b
Fresh Mesh	0 a	2.0 a	7.5 a
Control	0 a	1.9 a	6.7 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

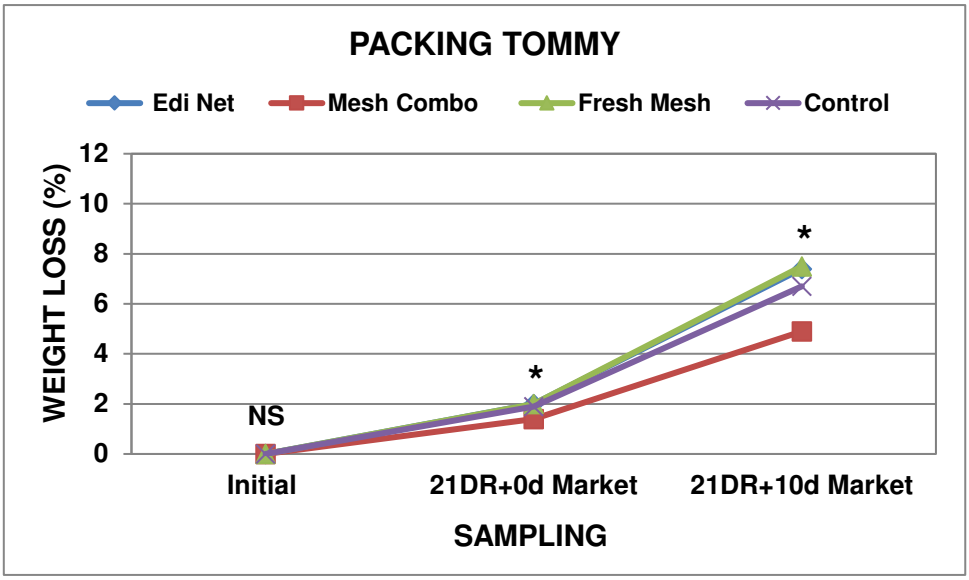


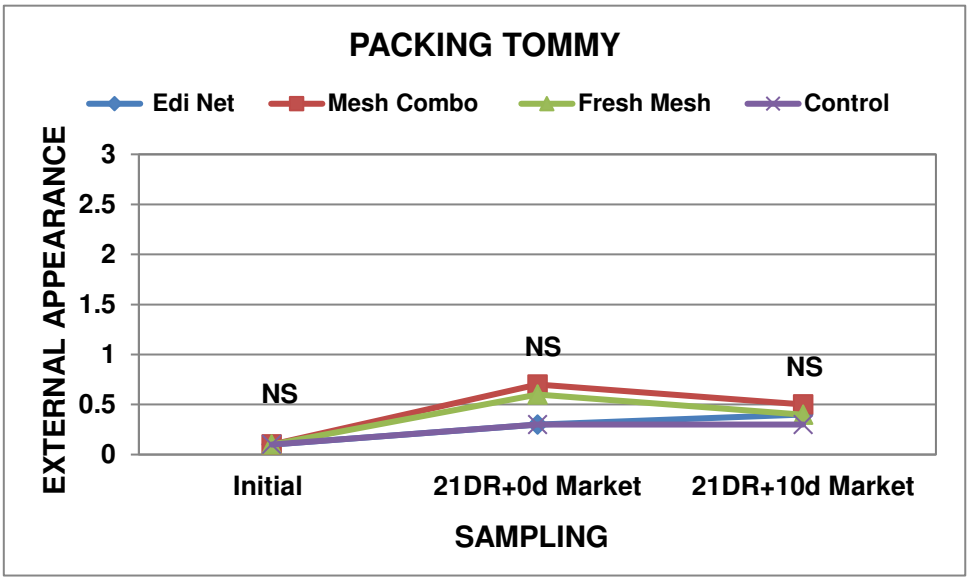
Figure 11. Weight loss (%) of 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Regarding to the external appearance of 'Tommy Atkins' fruit packed in different bags, no statistical differences were found among treatments (Table 10). It was observed in all the samplings that the values reached fluctuated between 0.1 and 0.7 (Figure 12), which means that in all the samplings the fruit showed the appearance of excellent to good, desirable for export fruit..

Table 10. External appearance of 'Tommy Atkins' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	0.1 a	0.3 a	0.4 a
Mesh Combo	0.1 a	0.7 a	0.5 a
Fresh Mesh	0.1 a	0.6 a	0.4 a
Control	0.1 a	0.3 a	0.3 a

Means with the same letter within columns are statistically equal (Duncan 0.05)



Scale 0 = Excellent 1 = Good 2 = Fair 3 = Poor

Figure 12. External appearance of 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Regarding to the fruit firmness in 'Tommy Atkins', it was observed that the initial values were around of 35 lbs. (Table 11) without statistical differences among treatments. It is worth mentioning that these values are much higher than those found in 'Ataulfo' and this is partly due to the fact that the 'Tommy Atkins' fruit was processed the same day of harvest and from a late flowering, while those of 'Ataulfo' showed relatively low firmness values because fruit was harvested very late in the season and with an advanced ripening degree. In the subsequent samplings, at the end of the refrigerated shipping simulation, any of the bags showed a higher value than the controls, and at consumption significant differences were observed between treatments, with the fruits packed in the Mesh combo bag showing the lowest value (Figure 13).

Table 11. Pulp firmness (Lbs) of 'Tommy Atkins' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Tratamiento	Initial	21DR+0 Market	At consumption
Malla EDI	35.6 a	30.8 ab	4.8 a
Mesh Combo	35.6 a	31.8 ab	3.0 b
Fresh Mesh	35.6 a	34.0 a	4.3 a
Testigo	35.6 a	25.6 b	4.4 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

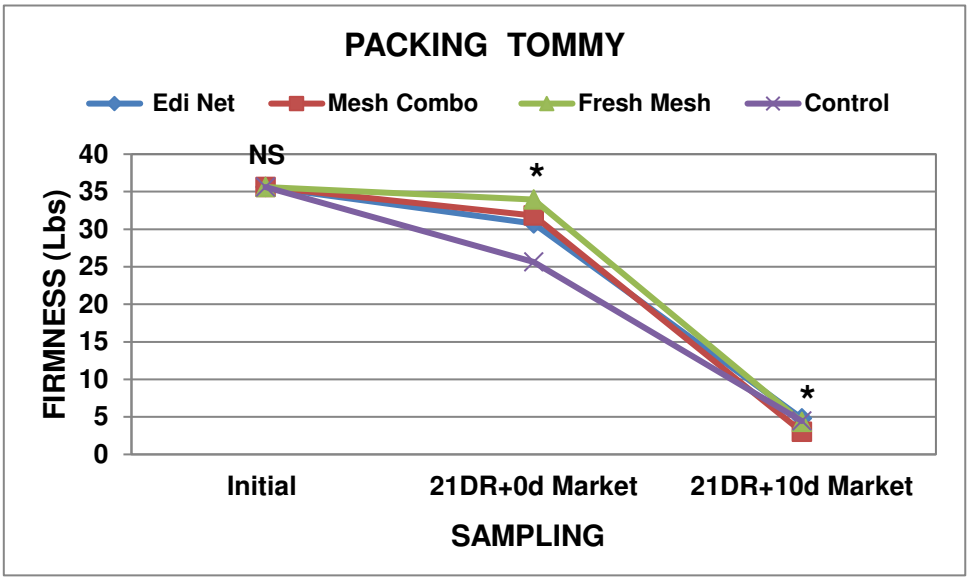


Figure 13. Firmness (Lbs) of 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

The color of the 'Tommy Atkins' fruit pulp is recorded in Table 12. No statistical differences were detected in the initial values, however, it was observed that the fruit had a maturity stage equivalent to value 2 of the EMEX table. At the end of the simulation of refrigerated shipping, significant differences were detected among treatments, with the fruit packed in the Fresh mesh bags having the lowest color

intensity. However, at consumption, no significant differences were detected among treatments, reaching acceptable color intensity for all of them. Observing the trend of pulp color (Figure 14), it was corroborated that all the fruit showed a very similar trend when increasing the intensity of the pulp color and only significant at the end of the simulation of the refrigerated shipment. Remember that in this scale larger numbers mean less intensity of the pulp color, while smaller numbers express more intense colors.

Table 12. Pulp color (Hue) of 'Tommy Atkins' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	95.5 a	91.1 b	84.0 a
Mesh Combo	95.5 a	91.4 b	83.7 a
Fresh Mesh	95.5 a	93.5 a	85.0 a
Control	95.5 a	91.1 b	85.3 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

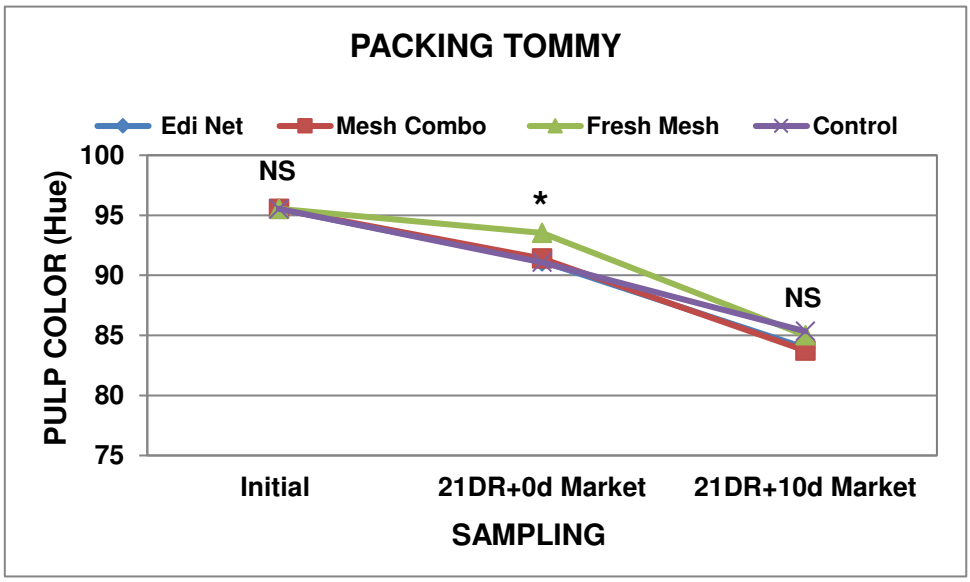


Figure 14. Pulp color (Hue) of 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

A very important variable in fruit quality is the content of total soluble solids (°Bx). It was observed that in none of the samplings statistical differences among treatments were detected and that at consumption the values reached were relatively low and this could be because fruit were harvested late in the season and not intended for export (Table 13). Figure 15 illustrates the behavior of the total soluble solids content in the 'Tommy Atkins' fruit. The expected trend of increase in the content was observed, however, as mentioned, no differences were detected among treatments and at consumption, the maximum value was 14.6 °Bx showed by the control fruit, but without statistical differences among all of them.

Table 13. Total soluble solids content (°Bx) of 'Tommy Atkins' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	8.2 a	12.6 a	14.3 a
Mesh Combo	8.2 a	12.3 a	13.5 a
Fresh Mesh	8.2 a	11.9 a	13.9 a
Control	8.2 a	12.9 a	14.6 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

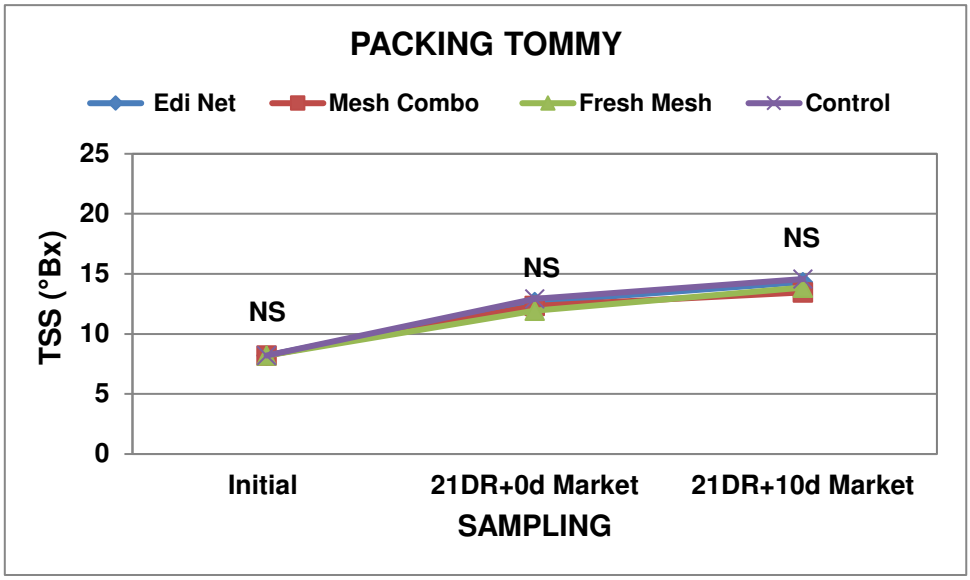


Figure 15. Total soluble solids content (°Bx) of 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Regarding to the acidity of 'Tommy Atkins' fruit packed in different containers, at the beginning it is possible to perceive the difference between 'Ataulfo' and 'Tommy Atkins', the former showed a very high value at harvest (3.4% citric acid), in so much so that the following only reached 0.59% citric acid without detecting a significant difference among treatments (Table 14). This trend continued at the end of the refrigerated shipping simulation, but upon consumption, the most acidic fruit was the control, statistically different from any of the bagged fruit. This trend is best observed in Figure 16, where no differences were observed in the first two samplings and only at consumption did the control show the highest values.

Table 14. Acidity (% citric acid) of 'Tommy Atkins' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	0.59 a	0.97 a	0.15 b
Mesh Combo	0.59 a	0.98 a	0.11 b
Fresh Mesh	0.59 a	0.87 a	0.14 b
Control	0.59 a	0.82 a	0.26 a

Means with the same letter within columns are statistically equal (Duncan 0.05)

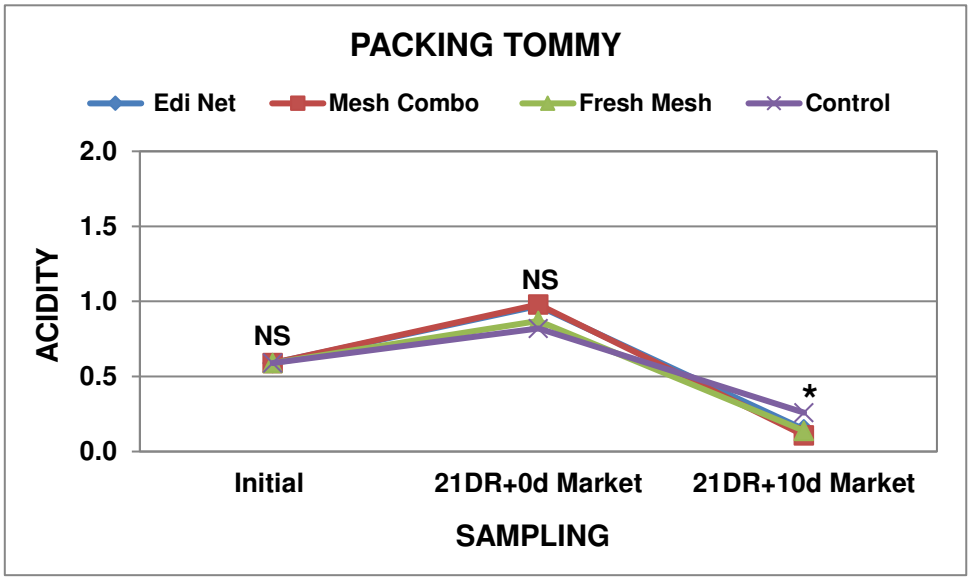


Figure 16. Acidity (% citric acid) of 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Another of the variables with the greatest impact on quality for consumption is the °Bx/Acidity ratio. Statistical differences among treatments were observed (Table 15). The fruit packed in the Mesh combo bag showed the best relationship (124.6), while the control fruit, the worst (56.3). The trend for a higher °Bx/Acidity ratio of any of the bags compared to the control was evident at consumption. The fruit from the Mesh

combo bag was the highest, which indicates a higher quality by having a better sweetness/acidity balance (Figure 17).

Table 15. Ratio Bx/Acidity of 'Tommy Atkins' fruit packed in different bags. Santiago Ixcuintla, Nayarit. 2020 season.

Treatment	Initial	21DR+0 Market	At consumption
Edi Net	13.9 a	13.0 b	96.8 b
Mesh Combo	13.9 a	12.6 b	124.6 a
Fresh Mesh	13.9 a	13.7 ab	100.4 b
Control	13.9 a	15.8 a	56.3 c

Means with the same letter within columns are statistically equal (Duncan 0.05)

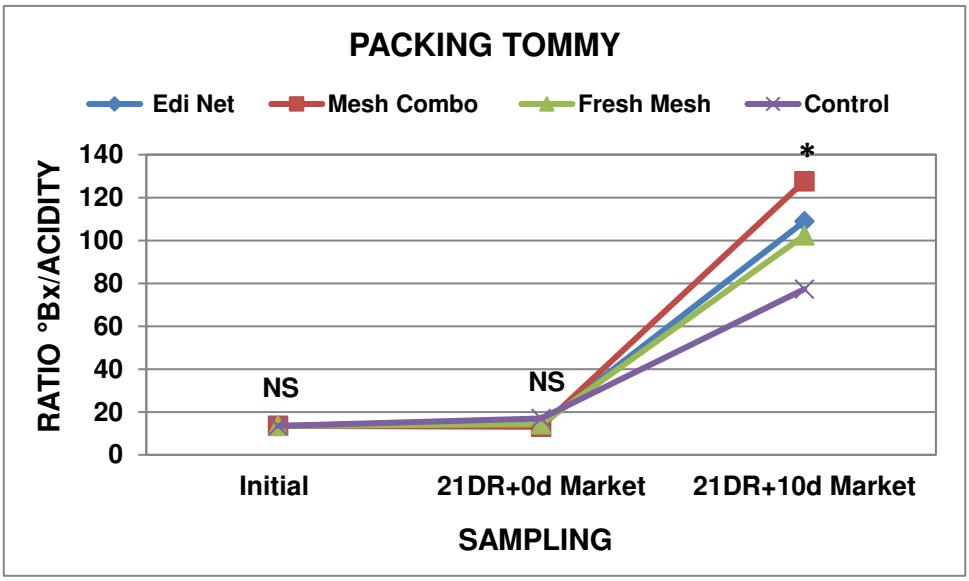


Figure 17. Ratio Bx/Acidity of 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

FRUIT GROWN IN ECUADOR

I. ATAULFO AND TOMMY ATKINS VARIETIES.

Results showed that practically no significant differences were detected for both varieties, except for weight loss. In ‘Ataulfo’, the treatment of Mesh combo bags stood out, since the fruit of this treatment showed a 27.3% lower weight loss than the control fruit. However, in ‘Tommy Atkins’ the best treatment was the Edi net, which showed only a third of the accumulated weight loss compared to the control fruit (Figure 18 A and B). Much higher accumulated weight losses were observed for 'Ataulfo' (10.9 to 17.4%) while for 'Tommy Atkins' they were from 1.3 to 3.6%, which was attributed to the fact that ripening degree of 'Ataulfo' fruit was greater than that of 'Tommy Atkins'.

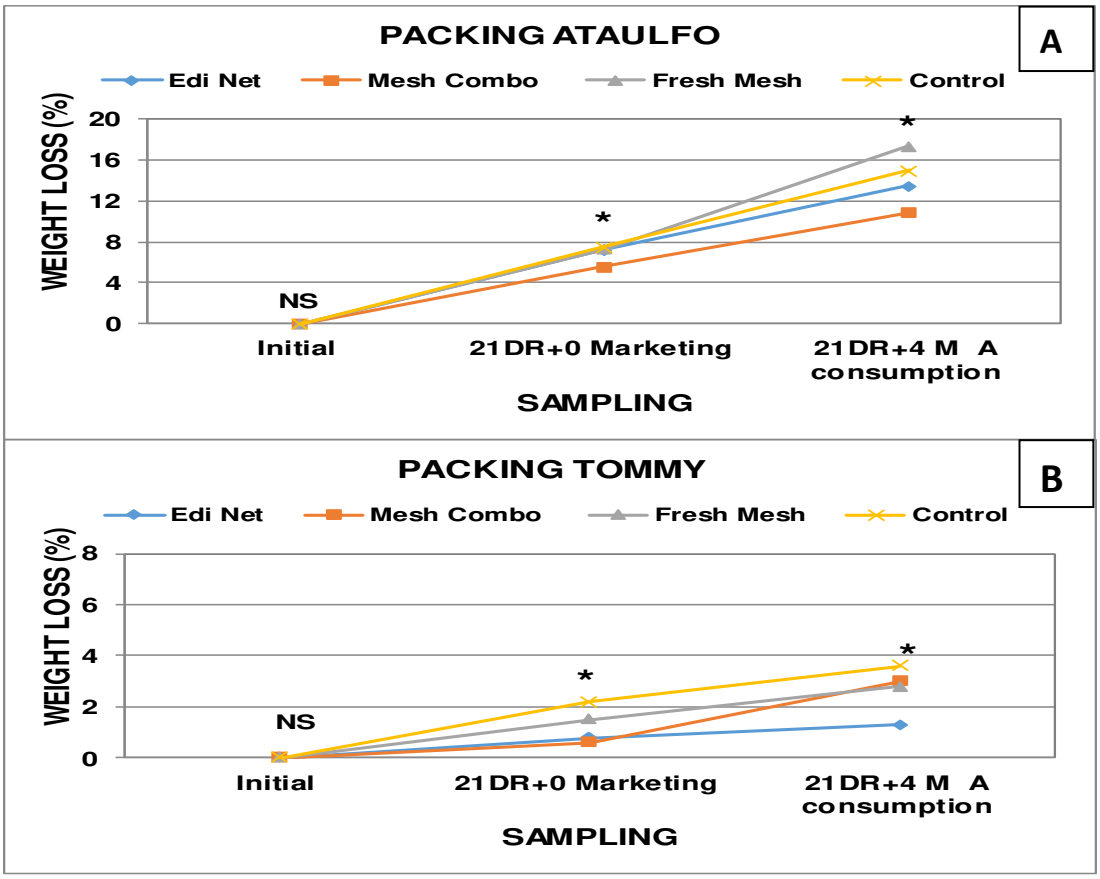


Figure 18. Weight loss (%) of ‘Ataulfo’ and ‘Tommy Atkins’ fruit packed in different breathable bags. Ecuador. 2020 season.

Regarding to the External Appearance, no significant differences were detected among treatments for both varieties. The initial values ranged between 0 and 1 (appearance from excellent to good, expected for export quality) and increased to values between 1 and 2 (appearance from good to fair) attributable to handling during shipment and received by the broker (Figure 19 A and B).

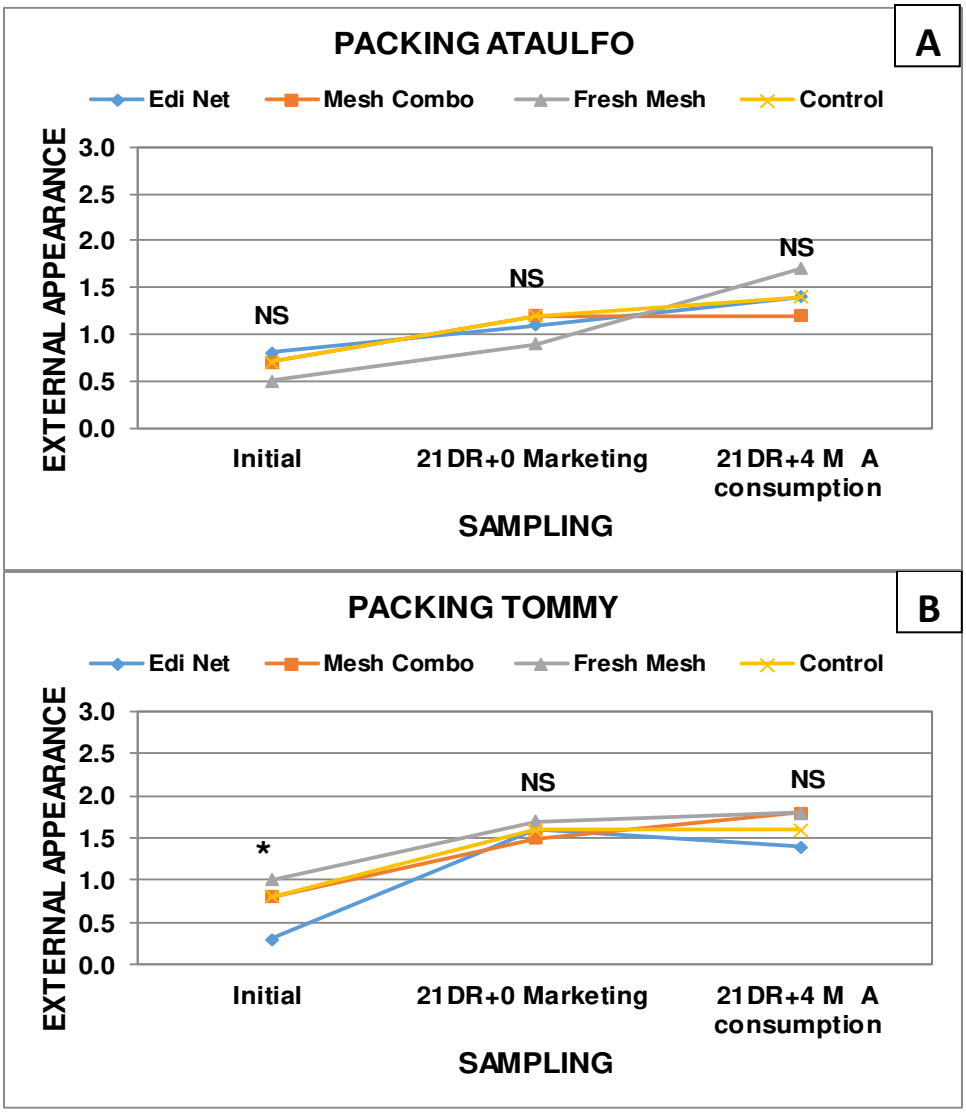


Figure 19. External appearance of 'Ataulfo' and 'Tommy Atkins' fruit packed in different breathable bags. Ecuador. 2020 season.

The pulp firmness advanced as expected, not detecting significant differences among the treatments for both varieties (Figure 20). The initial values of 'Ataulfo' (A) were around of 28 Lbs and those of 'Tommy Atkins' (B) about 21.7 Lbs, while at consumption was 1.7 to 2.0 Lbs in the first variety and 3.0 to 4.1 Lbs in the later.

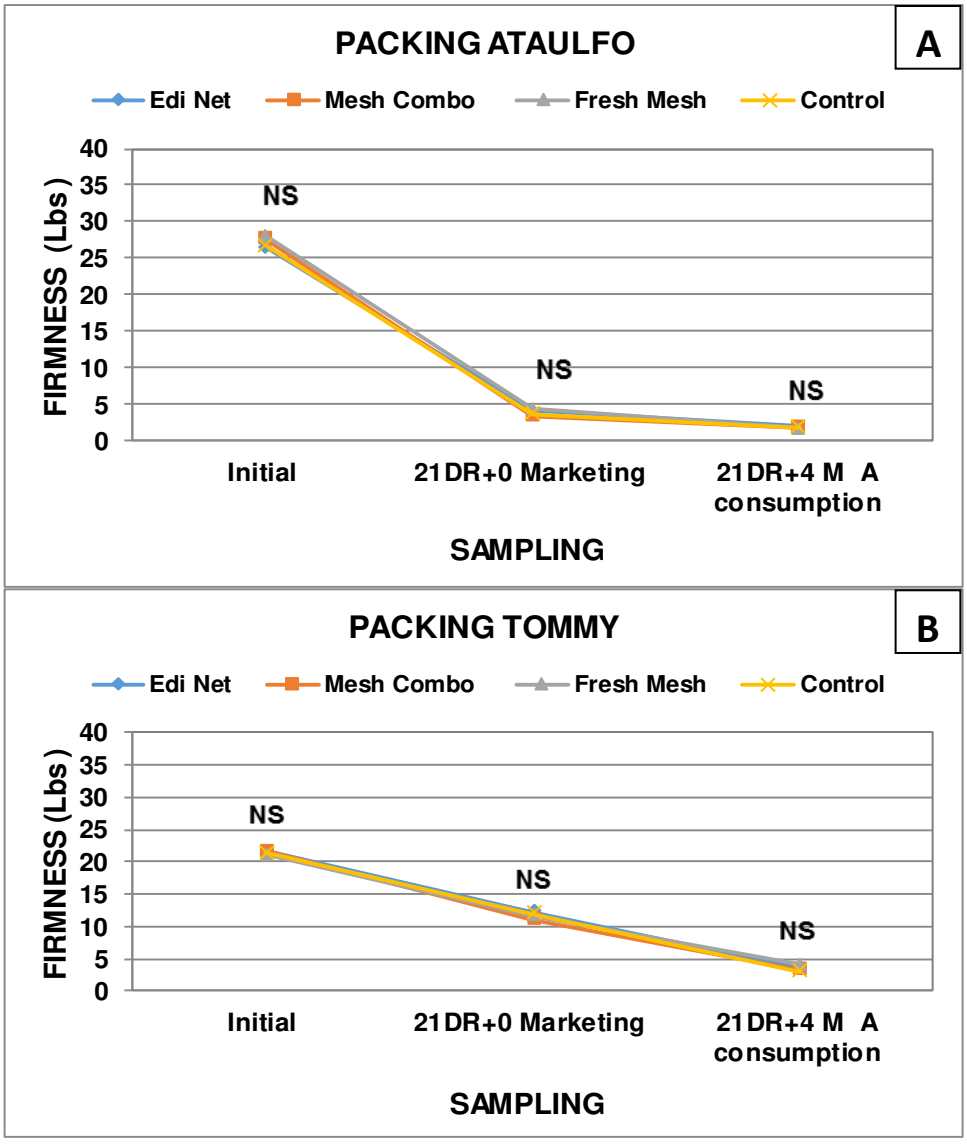


Figure 20. Firmness (Lbs) of 'Ataulfo' and 'Tommy Atkins' fruit packed in different breathable bags. Ecuador. 2020 season.

Regarding to pulp color, in 'Ataulfo' no significant differences were detected for the first two samplings (Figure 21A), only at the consumer sampling the fruit packed in the Mesh combo bags showed a more intense color (4.9) than any other of the other treatments. In contrast, in 'Tommy Atkins' differences were only detected at the beginning (Figure 21B), with the Mesh combo fruit being the ones with the highest color intensity. However, significant differences were no longer detected among treatments at the end of refrigeration and at consumption, reaching a maximum average value of 3.6 for table color.

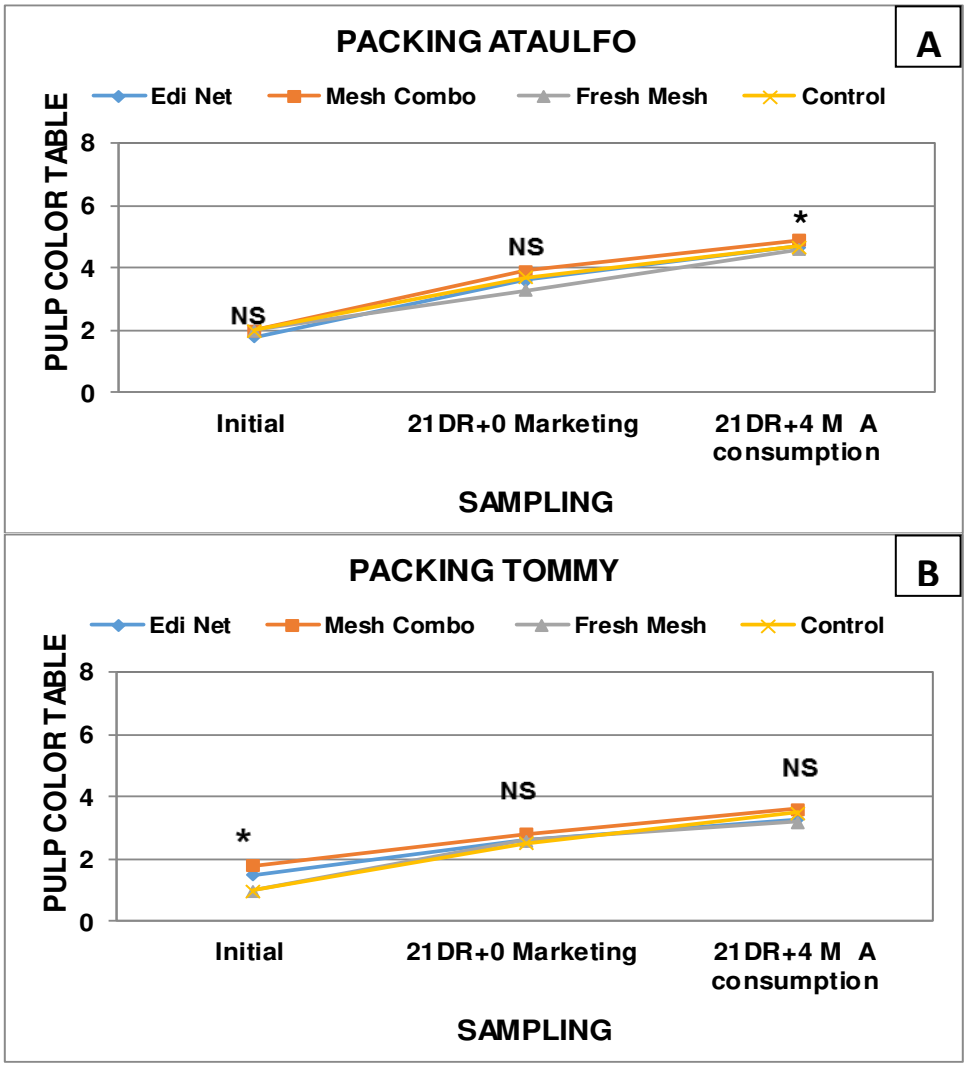


Figure 21. Pulp color of 'Ataulfo' and 'Tommy Atkins' fruit packed in different breathable bags. Ecuador. 2020 season.

Regarding to the content of total soluble solids, in 'Ataulfo' significant differences were detected for treatments at the beginning and at the end of refrigeration (Figure 22A). At the beginning, the Mesh combo and Fresh mesh treatments (10.4 and 10.7 °Bx, respectively) were equal to each other, but superior to the control and Edi mesh. In contrast, at the end of refrigeration, the best treatment was the Mesh combo with 18.2 °Bx. However, at consumption, no significant differences were detected among treatments. Regarding to 'Tommy Atkins' fruit, no significant differences were detected among treatments for any of the samples evaluated (Figure 22B).

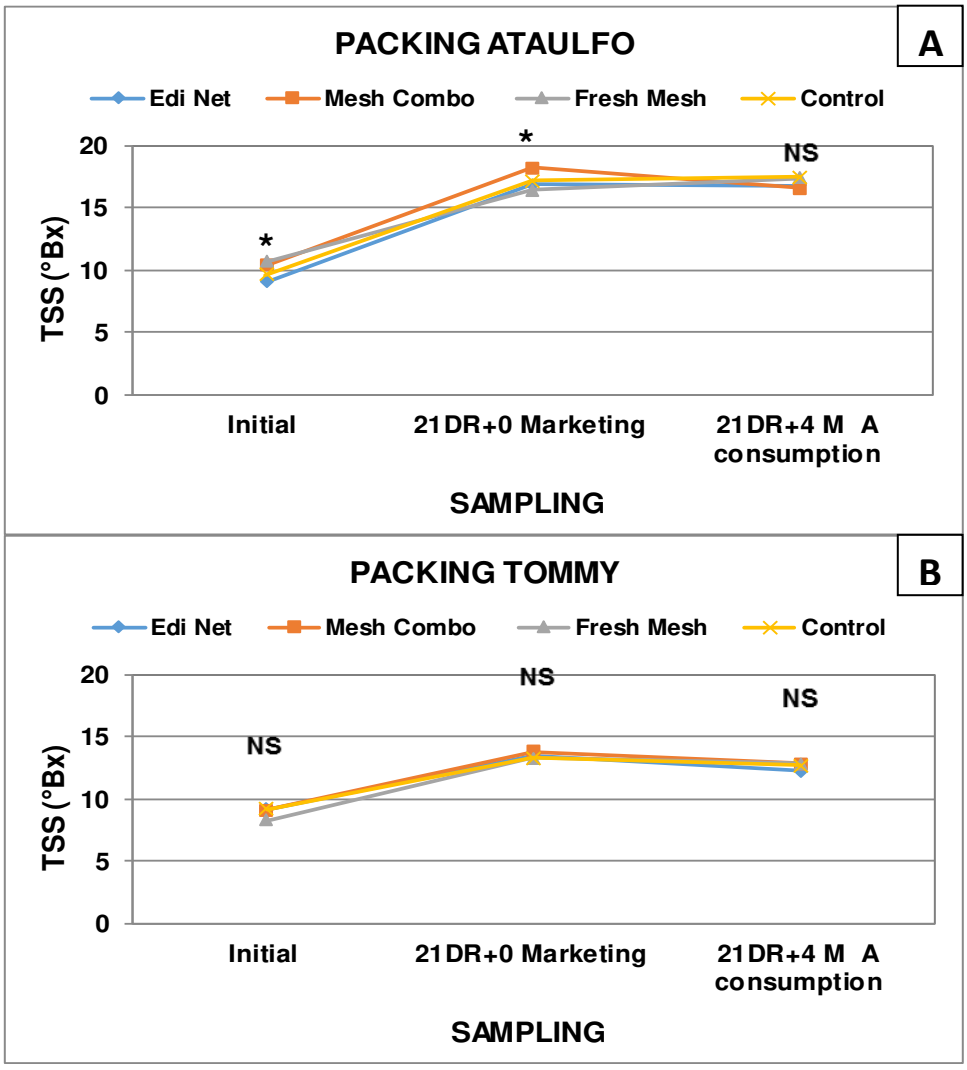


Figure 22. Total soluble solids (°Bx) of 'Ataulfo' and 'Tommy Atkins' fruit packed in different breathable bags. Ecuador. 2020 season.

CONCLUSIONS FOR FRUIT GROWN IN MEXICO

- Any of the bags was better than the control for most of the variables.
- The Mesh Combo bag stood out, which decreased weight loss and increased the °Bx/Acidity ratio in both varieties compared to the control fruit.
- The economic feasibility is viable since the cost of any of the bags is accessible (US $ 0.10 - 0.11).

CONCLUSIONS FOR FRUIT GROWN IN ECUADOR

- No significant differences were detected between treatments for most of the variables, except weight loss.
- In ‘Ataulfo’ the fruit from the Mesh combo treatment registered a less weight loss of 23.7% than the control.
- In 'Tommy Atkins' the best treatment was the Edi mesh, which showed only a third of the weight loss compared to the control.
- The economic feasibility is viable since the cost of any of the bags is accessible (US $ 0.10 - 0.11). It would only be necessary to corroborate the difference in sale by individual fruit or by a greater number of fruits (4 in ‘Tommy Atkins’ and 6 in ‘Ataulfo’).

SUGGESTIONS

- To repeat the test for the 2022 season as soon as there is ‘Ataulfo’ and ‘Tommy Atkins’ fruit in Nayarit evaluating the best treatment (Mesh combo), thr control and two more environmentally friendly alternatives (recyclable cardboard).

PROBLEMS OR DELAYS

- The 2021 season trial could not be rerun due to the dealer was unable to supply the recyclable cardboard boxes.

- On the other hand, in the semi-commercial trial there was an excellent cooperation from all the actors involved in the trial, from the directors and operatives of the Ecuador packinghouses, especially Angela León and Anderson Enrique Castañeda Anacleto, executors of the 'Ataulfo' and 'Tommy Atkins' rehearsals, respectively. Likewise, the Brokers (Robinson Fresh) John Thomas and Therman Johnson actively collaborated, as did Wanda Ramos, Rolf. Vladimir Mitton and Leo Ortega from the National Mango Board. Thanks to all of them and my apologies if someone got away from me.

PRESENTATIONS

In this activity, only the Final Report in Spanish and English was considered. There were no conference abstracts or published articles.

CONSULTED LITERATURE

AOAC. 1990. Official Methods of Analysis. 14th Ed. Published for the Association of Official Analytical Chemist Inc. Arlington, VA. 22209 USA. 1006 p.

Bix L., Seo W and Sundar P. 2013. The effect of colour contrast on consumers' attentive behaviours and perception of fresh produce. Packaging Technology and Science. 26: 96-104.

Brecht JK, Sargent SA, Kader AA, Mitcham EJ, Maul F, Brecht PE y Menocal O. 2011. Manual de prácticas para el mejor manejo postcosecha del mango. HS 1190. 78 p.

Fox Packaging. 2018. Produce Packing Solutions. www.foxbag.com

Osuna-García, J. A. 2018. Validación De La Técnica De Unidades Calor Para Determinar El Momento Óptimo De Cosecha En Las Principales Variedades De Mango Para Exportación INIFAP-CIRPAC. Campo Experimental Santiago Ixcuintla. Informe Técnico Convenio INIFAP-NMB.

U.S. Department of Agriculture. Animal and Plant Health Inspection Service. Plant Protection and Quarantine. 2010. Treatment manual. http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf

USDA Foreign Agricultural Service. 2018. Three years trends for U.S. mango imports. http://www.fas.usda.gov.

Ward R.W. 2014. Analizando la demanda de mangos con la National Mango Board. Reporte completo. 22 p.

Ward R.W. 2018. Impacto de los programas de la National Mango Board. Intensidad del mercado: promedio de mangos por comprador. Reporte completo. 73 p.

ANEXES

I. ATAULFO (VARIETY GROWN IN MEXICO)

Figure 23. External appearance 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Figure 24. Internal appearance 'Ataulfo' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

II. TOMMY ATKINS (VARIETY GROWN IN MEXICO)

Figure 25. Internal appearance 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

Figure 26. Internal appearance 'Tommy Atkins' fruit packed in different breathable bags. Santiago Ixcuintla, Nayarit. 2020 season.

I. ATAULFO (VARIETY GROWN IN ECUADOR)

Figure 27. External appearance 'Ataulfo' fruit grown in Ecuador packed in different bags. Ecuador. 2020 season.

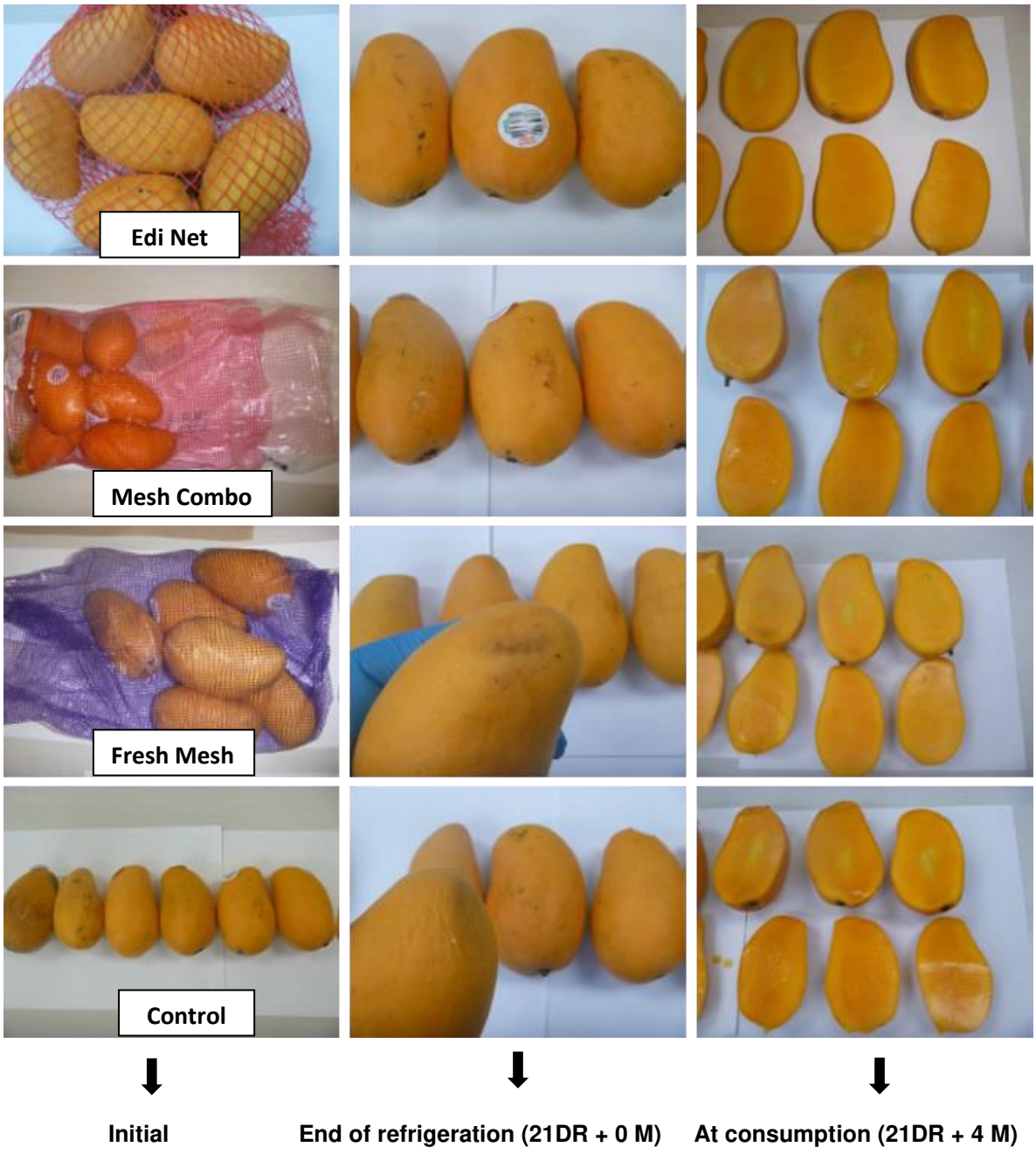


Figure 28. External and internal appearance 'Ataulfo' fruit grown in Ecuador packed in different bags. Ecuador. 2020 season.

II. TOMMY ATKINS (VARIETY GROWN IN ECUADOR)

Figura 29. External appearance 'Tommy Atkins' fruit grown in Ecuador packed in different bags. Ecuador. 2020 season.

Figure 30. External and internal appearance of 'Tommy Atkins' fruit grown in Ecuador packed in different bags. Ecuador. 2020 season.