Comparison of Pre-Cooling and Storage Processes for Fuji Apple Quality Maintenance using the Decision Support Method

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Abstract— *In Brazil the fruit growing is becoming more and more technified, obtaining with this better quality and productivity. As fruit varieties are regionalized and harvested at different times of the year, they need post-harvest conservation techniques to be offered in different regions of the country during the off-season. For these reasons, management of the Cold Chain (CC) logistic process in post-harvest refrigeration and preservation of fruits is the way to overcome these problems. In this context, the research aimed to analyze how the TODIM Method of Multicriteria Decision Support contributes to the process of comparing forced air pre-cooling (24hs) and cold storage (30 Days and 60 Days, CAT1 - 80 and CAT1 - 198) in Normal Atmosphere (NA) and Controlled Atmosphere (CA) 24hs. The methodological procedures adopted were: exploratory and descriptive research, with qualitative approach and field research. In the field research carried out at the Cooperserra cooperative, the following results were identified: (1) feasibility of the implantation of the rapid precooling process to the hydrocooling by immersion proving to be efficient in the application of the system, in relation to the precooling for forced-air cooling in the chamber combined with storage; (2) the management of the Cold Chain (CC) logistic process in the pre-cooling and storage stages maintains the quality of the Fuji apple (Malus Communis). In addition to contributing to academic research, the study corroborated the development of best practices in the management of the Cold Chain (CC) logistics process and commercialization, providing elements for companies to plan the logistics processes incorporating the precooling and storage stages of the Fuji apple (Malus Communis). It was concluded that in the pre-cooling to the cold water, it does not need that the apple stays for 24 hours in the cold chamber to reach the appropriate temperature of 2° C, it was verified that in 25 minutes of cooling the fruit reaches the temperature of 5ºC , maintaining the quality of the fruit and optimizing the energy expenditure of the cold room.*
Keywords— Fruticulture, Precooling, Storage.

I. INTRODUCTION

In Brazil, the fruit growing is becoming more and more technified, obtaining high productivity and quality. According to Vitti (2008), the production of each fruit has characteristics regionalized in different countries as well as at different times of the year, so it is necessary to improve the techniques of post-harvest conservation of these fruits, so that they can be offered in different regions of the country. country in the offspring of culture. For these reasons, the use of refrigeration in post-harvest conservation has become the primary means of overcoming these problems.

Fruit-growing is among the main sectors that generate income, employment and rural development for the national agribusiness (KoseraNeto, 2015). The productivity indexes and the commercial results obtained in the last harvests are factors that demonstrate the vitality as well as the potential of this productive segment.

Brazilian apple production has expanded significantly in the last two decades. In addition to the tradition of more than 30 years in the commercial cultivation of fruit, factors such as the production of modern varieties, availability of land, regions with favorable climatic conditions, as well as concerns about productivity, packaging infrastructure and conservation, have transformed Brazil into a world producer of apples (Bittencourtet al., 2011).

In this context, refrigeration has benefits to maintain the quality of the fruit, since its principle is to reduce the metabolism of the vegetable by reducing the temperature, also reducing the microbial growth rate (Degaspare, 2004).

Rapid cooling technologies are part of Cold Chain (CC), which Cold Chain Management (2004) defines as

consistency in maintaining adequate cooling of the environment for products that require special treatments, properly controlled during the accomplishment of the logistic steps , ensuring the quality of the fruit.

According to Cárioand Seabra(2010), in the region of São Joaquim, the production is concentrated in the apple cultivars Fuji (Malus Communis) and Gala. The apple Gala (Malus Domestica Bork) harvests in the months of February and March each year, while the harvest of the Fuji apple (Malus Communis) occurs in the months of April and May. With this difference of harvest period, the fact that the production of the region is divided in the two cultivars, favors the optimization of resources in the harvest and post-harvest stages.

After the harvest, the rapid precooling process, understood as the rapid removal of the field heat from the products, should be one of the first steps to guarantee advantages such as: the consumption of a better quality product, reduction of losses for the merchant , increased storage and marketing time, profit maximization and cost minimization. In this research the Multicriteria Analysis Methodology (AMD) was used, the TODIM method was applied to compare the results.

II. MULTIRITERARY METHODS OF SUPPORT FOR THE DECISION

According to Vieira (1999, p.12), "multicriteria methods try to represent the preferences of the decision maker in the best possible way, even when those preferences present some inconsistency." Moreover, one can say that the purpose of these methods is not to find solutions, but rather to recommend actions considered satisfactory, in the context of the problem being analyzed.

To Gomes, Gomes and Almeida (2006, p. 36) "The Multiple Criteria Decision Support (AMD) is a set of methods and techniques to assist or support people and organizations to make decisions under the influence of a variety of criteria," the application of any method of multicriteria analysis presupposes the need of previous specification on what objective the decision maker intends to achieve, when the comparison is proposed among several decision alternatives, using multiple criteria.

AMD methods are tools to support decision making in complex situations, when there are several potential actions (not necessarily alternatives) to be analyzed in the light of several criteria (Vieira, 1999).

Multicriteria Decision Support can be seen as a set of methods that lend themselves to clarifying a problem in which alternatives are evaluated by multiple criteria, which are conflicting in most cases (Oliveira et al., 2016).Multicriteria methods have been developed to support and guide decision-makers in the evaluation and choice of solution alternatives in different spaces.

According to Gomes, Gomes and Almeida (2006).

The space of decision variables, in particular, consists of the set of feasible and non-feasible decisions for a given problem. The decision-making process is highly complex in a company since a decision may involve several alternatives with different consequences and numerous criteria to analyze. The purpose of the Multicriteria approach is to help decision makers organize and synthesize information in the way they can feel confident about decision making. (Belton & Stewart, 2002).

In group decisions, individual preferences can be combined to result in a group decision. Actions are linked to the decision variables that must be decided and communicated, the decision of the group is the consequence of an exchange of decisions (Eissmann et al., 2017).

There are two large families of multicriteria methods, whose origins refer to the American and European (notably French) schools of Multicriteria Decision Support. The American school is characterized by the decomposition of the problem of decision in hierarchical levels and also by the comparison of the alternatives, pair by pair, whereas the methods of the French School do not require the decomposition of the problem in hierarchical levels and also do not require the comparison of the alternatives at the same time (Vieira, 1999).

The main method of the American School is the AHP method - "Analytic Hierarchy Process". One of the methods of the French School is the Promethean method. In this research there is a special interest in the TODIM method "Multicriteria Interactive Decision Making", conceived by Professor Luiz FlávioAutran Monteiro Gomes, from the Fluminense Federal University.

Todim Method (Multicriteria Interactive Decision Making)

For Vieira (1999), "in its initial stage the TODIM (Multicriteria Interactive Decision Making) method consists of comparing pairs of alternatives, in light of each of the analysis criteria, by means of a function that represents dominance) of one alternative over another. " We can present some characteristics TODIM Method:
  a) good levels of transparency and intelligibility;
  b) adequacy to the discrete problem of ordering potential actions;
  c) minimization of the possibility of occurrence of order reversal;
  d) adequacy to the solution of hierarchically structured problems;
  e) incorporation of the concepts of Perspective Theory.

The multicriteria TODIM method, which, besides the advantage of trying to model the patterns of preference

when risk decisions are made, using the Prospective Theory (Kahneman&Tversky, 1979) allows both quantitative and qualitative criteria to be worked on. has a satisfactory degree of intelligibility compared to other discrete methods (Gomes and Duarte, 1998).

According to Gonzalez, Gomes and Rangel (2012) to perform the application of this model to a database derived from calculations and value judgments, the TODIM method must evaluate characteristic forms of the functions of losses and gains. These will serve to construct the additive difference function of the method, which equips measures of dominance of each alternative in relation to the other alternatives.

Although it seems complex to have to test that adaptation of the paradigm to the database, which could eventually force the decision analyst to use other forms of the functions of losses and gains, in fact it is not since the first uses of the TODIM method, in the early nineties of the last century, the same mathematical forms have been successfully employed (Oliveira et al., 2017a; Oliveira et al., 2017b; Oliveira et al., 2017c).

Gomes and Duarte (1998) consider the "TODIM method a set of n alternatives to be ordered in the presence of m, quantitative and qualitative criteria". While the valuations of the alternatives against the quantitative criteria are obtained by, for example, some measure, as in the case of the criterion "prevalence of the disease in question", the valuations of the alternatives according to the qualitative criteria are obtained through value judgments read on a cardinal scale or on a verbal scale.

These scales are used to order alternatives to the criteria and also to weigh the criteria. Using verbal scales, value judgments are converted to numerical values read on the corresponding cardinal scale. An example of such a scale is shown in the following table:

Table.1: Correspondence between cardinal and verbal scales

Intensidade da importância	Definição	Alternativas x Critérios (c)
1	muito pouca importância	alternativa i-muito pouca importância para c
2	pouca importância	alternativa i-pouca importância para c
3	alguma importância	alternativa i-alguma importância para c
4	grande importância	alternativa i-grande importância para c
5	Importância absoluta	alternativa i-absoluta importância para c

Souce: Gomes andDuarte (1998).

or each of the qualitative criteria c, a specialist should estimate the contribution of each alternative i to the objective associated with criterion c. Thus, if$w_{ic}$is an estimate of the contribution of alternative i to the maximization of criterion c, this estimate is expressed by a weight on a cardinal scale or by means of a reading on the corresponding verbal scale. Since there is a correspondence between the readings on the verbal scale and the cardinal scale, the performance matrix of the alternatives will contain only numerical values in their cells.

The following additive difference function is used to determine the dominance of one alternative over the other:

$$\delta(i,j) = \sum_{c=1}^{m} \phi_c(i,j)$$

where φ c (i , j) is called the partial dominance function of alternative i over j and its expression:

$$\phi_c(i,j) = \begin{cases} \sqrt{\dfrac{a_c(w_{ic} - w_{jc})}{\sum_c a_c}} \\ -\sqrt{\dfrac{\left(\sum_c a_c\right)(w_{jc} - w_{ic})}{a_c}} \end{cases}$$

being δ(i,j) is the measure of dominance of alternative*i* over alternative *j*.Ifδ(i,j) > 0,the alternative *i*dominates the alternative *j*, that is the alternative *i* is preferable the alternative *j*; if δ (i, j) = 0 the alternatives*i* and *j* are equal.

m = number of criteria;

c = any criterion, c = 1, ..., m;

ac = weight of criterion c normalized;

$W_{ic}W_{jc}$ = weights of the alternatives i and j, respectively, in relation to the criterion c.

It should be noted that $W_{ic} - W_{jc} > 0$ represents a relative gain, while $W_{ic} - W_{jc} < 0$ represents a relative loss. The total values of the various alternatives are combined to produce an ordering using the expression 1.3.

$$\xi_i = \frac{\sum_{j=1}^{n}\delta(i,j) - \underset{i}{Min}\sum_{j=1}^{n}\delta(i,j)}{\underset{i}{Max}\sum_{j=1}^{n}\delta(i,j) - \underset{i}{Min}\sum_{j=1}^{n}\delta(i,j)}$$

After the calculation of the several matrices of partial dominances, one for each criterion, the final dominance matrix is obtained, through the sum of the elements of the several matrices.

Table.2: Matrix of final dominance

Alternativa	1	2	3		i			n
1	$\delta(1,1)$	$\delta(1,2)$	$\delta(1,3)$		$\delta(1,i)$			$\delta(1,n)$
2	$\delta(2,1)$	$\delta(2,2)$	$\delta(2,2)$		$\delta(2,i)$			$\delta(2,n)$
3	$\delta(3,1)$	$\delta(3,2)$	$\delta(3,3)$		$\delta(3,i)$			$\delta(3,n)$

Source: Gomes and Duarte (1998).

This matrix will be normalized using the expression (1.3) to obtain the global values of the alternatives. Each number calculated by expression (1.3) above is to be interpreted as the measure of the overall desirability or utility or simply value of a given alternative.

The formulation of the TODIM Method

Consider a set of n alternatives to be ordered in the presence of m, quantitative and qualitative criteria. The contributions of alternatives i and j to the maximization (or minimization) of criterion c, are $w_{i,c}$ and $w_{j,c}$, respectively. These contributions, when the criterion c is quantitative, are obtained, for example, by means of a measure - average area of housing in the segment, for example. The contributions of alternatives *i* and *j* when the criterion *c* is qualitative are obtained by value judgments read directly on a cardinal scale or on a verbal scale - when using the latter, it will always be related to the first. The mentioned scales are also used to weigh criterion c - and the other criteria. Consider also that ac is the weight assigned to criterion c. In the multicriteria environment, the gains and losses in the comparison of alternatives i and j, according to criterion c, are perceived by analyzing the difference between wi, c and wj, c. Thus, the partial (preference) dominance of alternatives i over the alternative j according to criterion c, is given by:

ϕ_c (i,j) = a_c . arctg ($w_{i,c}$ e $w_{j,c}$) , se $w_{i,c}>w_{j,c}$

In this case it is said that alternative i dominates (or is preferred in relation to ...) alternative j. The function ϕ_c (i,j) is an arc-tangent function since, as described above, this is the function to be used in the earnings field.
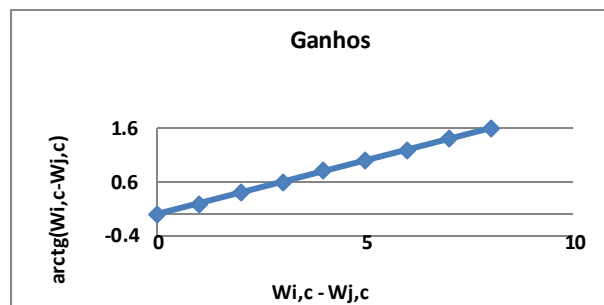

Fig.1: Gains represented by the Arc-tangent Function

Source: Vieira (1999).

If, on the other hand, alternative i is dominated by alternative j according to criterion c, the partial dominance function is given by:

ϕ_c (i,j) = -a_c .$\sqrt{- (wi, c\ e\ wj, c)}$, if $w_{i,c}<w_{j,c}$.

The function ϕ_c (i,j) is a square root function, because as described above, this is the function to be used in the loss terrain.
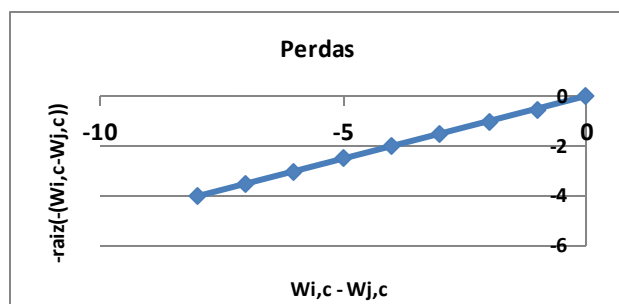
Fig.2: Losses represented by the Square Root Function
Source: Vieira (1999).

Of course, if alternative i is equivalent to alternative j according to criterion c, the partial dominance function is given by:

$\phi_c (i,j) = 0$, if $w_{i,c}$ e $w_{j,c}$

Once the matrices are calculated $\phi_c(i,j)$ for each of the m criteria, the second step of the TODIM method consists of aggregating the partial preferences (dominances) calculated in a matrix of final preferences, which is given by:

$$\delta (i,j) = \sum_{C=1}^{m} \phi c (i,j) \qquad , \qquad \forall (i,j).$$

The final step of the TODIM method consists of calculating the final preference of each of the alternatives, so that it is possible to identify from the best to the worst alternative. The final preference (dominance) of alternative iis given by:

$$\epsilon_i = (\sum_{j=1}^{n} \delta (i,j)$$
$$- \operatorname{Min} i \sum_{j=1}^{n} \delta (i,j) / (\operatorname{Max} i \sum_{j=1}^{n} \delta (i,j)$$
$$- \operatorname{Min} i \sum_{j=1}^{n} \delta (i,j))$$

In fact, the first member of the previous expression, $\sum_{j=1}^{n} \delta (i,j)$), already represents the final preference of alternative i, insofar as it aggregates the comparisons of alternative i, pair by pair, with all other alternatives. What the expression does is a scale change, so that all preferences are in the range [0 , 1].

MATERIALS AND METHODS

Setting the Study Scenario
The proposed scenario of the study will be defined based on two important attributes: pre-cooling and storage (conventional and controlled atmosphere), shown in Figure 3.
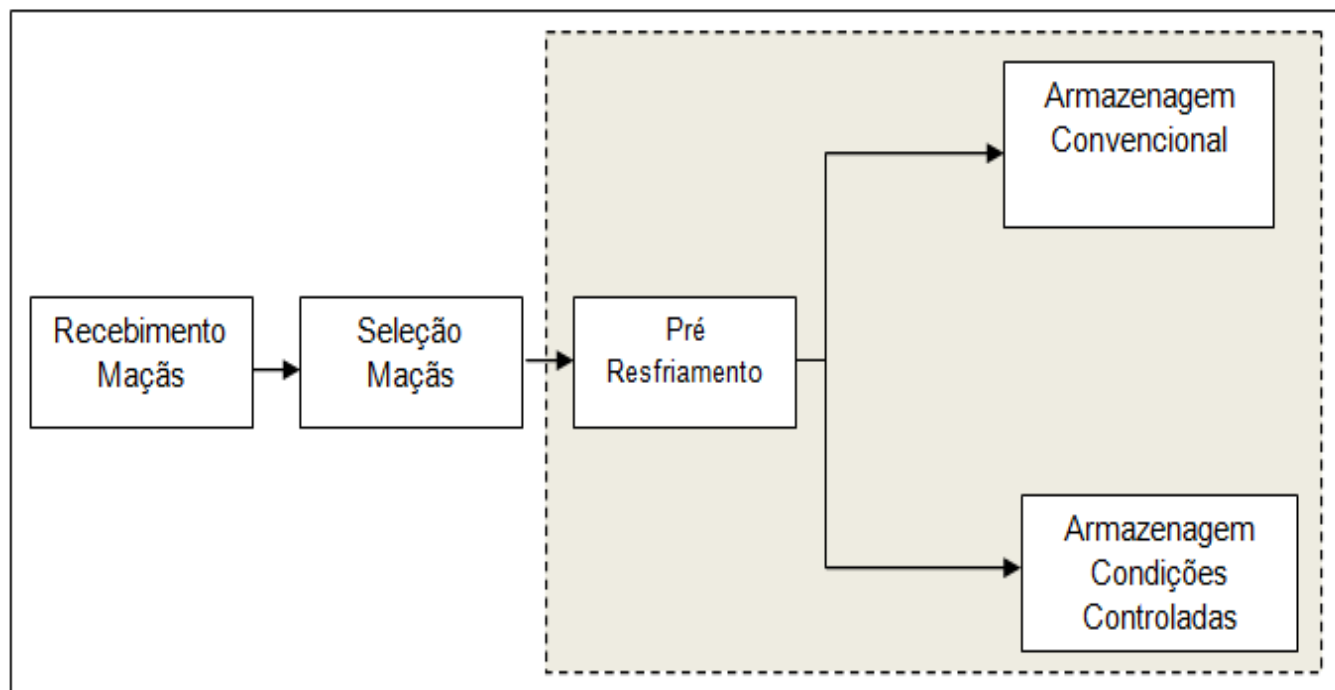

Fig.3: Study Scenario

The simulation in the study scenario involved the processes of precooling the hydrocooling and pre-cooling by forced air in the storage chamber, with the objective of rapidly reducing breathing and perspiration processes in function temperature and time, constituting the first stage of the cold chain and conventional storage under controlled conditions (Pacheco Costa, et al., 2017).

According to Teruel et al. (2001) both systems, forced air and water, guarantee low cooling times. Even so, the forced air circulation system usually cools 1/4 to 1/10 of the time required in conventional chambers, but is still two to three times slower than cooling with ice water. The relationship between time and temperature is what characterizes the cooling efficiency, so the lower the cooling time, the greater the efficiency of the system, which translates into products that maintain their quality and a shelf life of larger shelf.

Conducting Research

The research was conducted at the Cooperserra cooperative in São Joaquim/SC. In the first stage, seventy experiments were carried out with five Fuji (Malus Communis) 80 CAT1 and 198 CAT1 samples from orchards located in the municipality of São Joaquim/SC. The fruits harvested in commercial maturation in the harvest of April 2017. After the harvest, the fruits were transported to the Packing House of the cooperative.

The fruits were selected for size and maturation stage, eliminating those with physical defects and physiological disorders. They were then washed in running water and treated with 1% aqueous chlorine solution. Subsequently, they were packed in cardboard boxes and transported by truck, without refrigeration to the chemistry laboratory of the Universidade do Planalto Catarinense - UNIPLAC in Lages/SC.

The treatments evaluated were: Pre-forced air cooling (24hs) and cold storage (30 Days and 60 Days, CAT1 - 80 and CAT1 - 198) in Atmospheric Normal and Controlled Atmosphere 24hs.

Pre-cooling and storage process (30 days and 60 days, CAT1 - 80 and CAT1 - 198) by forced - air cooling in the cold room

On 06/26/2017, the experiments for pre-cooling by forced air (forced-air cooling) and storage in the cold room for 24 hours at 1ºC were sent to the cooperative in São Joaquim/SC denominated: Atmosphere Normal (60 Days - CAT 1 - 80), (30 Days - CAT 1 - 198) and (60 Days - CAT 1 - 198) Controlled Atmosphere (30 Days - CAT 1 - 80), (60 Days - CAT 1 - 80), (30 Days - CAT 1 - 198) and (60 Days - CAT 1 - 198).

Fruits denominated (30 days - CAT 1 - 80), (60 Days - CAT 1 - 80), Normal Atmosphere and Controlled Atmosphere

The fruits were pre-cooled in the chamber for 24 hours at 1ºC and later stored 30 and 60 days in Normal Atmosphere. On July 28, 2017 the second stage of the research was started, the fruits stored in the period of 30 days (CAT1 - 80) in Normal Atmosphere were separated, the experiments 1 and 3 were separated called Shelf (7 Days and 14 Dias), were placed in ambient conditions, remaining seven days and fourteen days of exposure under the same conditions of commercialization.

The analysis of the samples of the experiments 2, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity. On the same date, the fruits stored in the Controlled Atmosphere (CA) were stored for 30 days (CAT1 - 80), the experiments 1 and 2 were separated, called Shelf (7 Days and 14 Days), placed under ambient conditions, remaining seven days and fourteen days of exposure under equal conditions of commercialization. The analysis of the samples of the experiments 3, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity.

On 30/08/2017 the third stage of the research was started, the fruits stored in the period of 60 days (CAT1 - 80) in Normal Atmosphere were separated, the experiments 1 and 2 denominated Shelf were separated (7 Days and 14 Days), were placed in ambient conditions, remaining seven days and fourteen days of exposure under the same conditions of commercialization. The analysis of the samples of the experiments 3, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity.

On the same date, the fruits stored in the Controlled Atmosphere were stored at 60 days (CAT1-80), the experiments 1 and 2 were separated, called Shelf (7 Days and 14 Days), placed at ambient conditions, remaining seven days and fourteen days of exposure under equal conditions of commercialization. The analysis of the samples of the experiments 3, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity.

On August 8, 2017, samples of the Shelf Stable (7 Days, CAT1 - 80) Normal Atmosphere of the Experiment

2 were analyzed. The experiment was carried out in the cooperative laboratory. the color of the epidermis and the rot of the fruits, and the analysis of ºBrix, Pressure (firmness of the pulp) and titratable acidity. At the same time, the samples were analyzed (7 Days, CAT1 - 80) Controlled Atmosphere of the experiment 2, carried out in the laboratory of the Cooperative, started with the measurement of the temperature of the pulp in the sequence. color of the epidermis and fruit rot, and the analysis of ºBrix, Pressure (pulp firmness) and titratable acidity.

On 08/08/2017, samples of the Experimental 1 Shelf (14 Days, CAT1 - 80) Normal Atmosphere were analyzed and the temperature of the pulp was measured. the color of the epidermis and the rot of the fruits, and the analysis of ºBrix, Pressure (firmness of the pulp) and titratable acidity. On the same date, the samples called the Shelf (14 Days, CAT1 - 80) Controlled Atmosphere of experiment 1, carried out in the laboratory of the Cooperative, were analyzed by the measurement of the temperature of the pulp in the sequence. color of the epidermis and fruit rot, and the analysis of ºBrix, Pressure (firmness of the pulp) and titratable acidity. The research data was presented in Chapter 5, item 4.

Fruits denominated (30 Dias - CAT 1 – 198), (60 Dias - CAT 1 – 198), Normal Atmosphere (NA) and Controlled Atmosphere

The fruits were pre-cooled in the chamber for 24 hours at 1ºC and later stored 30 and 60 days in Normal Atmosphere. On July 28, 2017 the second stage of the research was started, the fruits stored in the period of 30 days (CAT1 - 198) in Normal Atmosphere were separated, the experiments 1 and 2 were separated, called the Shelf (7 Days and 14 Days), were placed in ambient conditions, remaining seven days and fourteen days of exposure under the same conditions of commercialization.

The analysis of the samples of the experiments 3, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity (TA).

On the same date, the fruits stored in the Controlled Atmosphere (CA) were stored for 30 days (CAT1 - 198), the experiments 1 and 2 were separated, called Shelf (7 Days and 14 Days), placed under ambient conditions, remaining seven days and fourteen days of exposure under equal conditions of commercialization.

The analysis of the samples of the experiments 3, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity (TA).

On August 30, 2017 the third stage of the research was started, the fruits stored in the period of 60 days (CAT1 - 198) in Normal Atmosphere were removed, the experiments 1 and 2 denominated Shelf were separated and 14 days), were placed in ambient conditions, remaining seven days and fourteen days of exposure under the same conditions of commercialization.

The analysis of the samples of the experiments 3, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity (TA).

On the same date the fruits stored in the Controlled Atmosphere (CA) were stored at 60 days (CAT1 - 198), the experiments 1 and 2 denominated Shelf were separated (7 days and 14 days), placed under ambient conditions, remaining seven days and fourteen days of exposure under equal conditions of commercialization.

The analysis of the samples of the experiments 3, 4 and 5, started with the measurement of the temperature of the pulp in the sequence was observed the color of the epidermis and the rot of the fruit, and the analysis of ºBrix, Pressure (firmness of the pulp) and Titlutable acidity.

COMPARISON OF FRUIT PROCESSES (CAT1 - 80 AND CAT1 - 198) - TODIM METHOD

In the second stage, results obtained by means of the multicriteria modeling of forced-air pre-cooling parameters on the quality of the fruit during the storage period in the cold room were evaluated. The following evaluation and comparison parameters are as follows:

Pulp temperature;

ºBrix;

Pressure (Firmness of Pulp); and,

Tit Titratable Acids.

We used the TODRI multicriteria method that, besides the advantage of trying to model the patterns of preference when risk decisions are made, using the Prospective Theory (Kahneman &Tversky, 1979), allows to work with both quantitative and qualitative criteria and has a satisfactory degree of intelligibility compared to other discrete methods(Gomes andDuarte, 1998). In the multicriteria environment, the gains and losses in the comparison of alternatives i and j, according to criterion c, are perceived by analyzing the difference between $w_{i,c}$ and $w_{j,c}$.

Thus, the partial (preference) dominance of alternatives i over the alternative j according to criterion c, is given by:

$$\phi_c\,(i,j) = a_c \cdot arctg\,(w_{i,c}\ e\ w_{j,c})\quad,\quad if\,w_{i,c}{>}w_{j,c}$$

If, on the other hand, alternative i is dominated by alternative j according to criterion c, the partial dominance function is given by:

$$\phi_c\,(i,j) = -a_c \cdot \sqrt{-\,(w_{i,c}\ e\ w_{j},\ c)},\ \text{if} w_{i,c} < w_{j,c}.$$

The function ϕ_c (i,j) is a square root function, because as described above, this is the function to be used in the loss terrain. The comparison between the Pre-cooling and Storage processes of the following treatments:

Camera 24hs (30 days NA);
Chamber 24hs (30 days BC);
Camera 24hs (60 days NA); and,

House 24hs (60 days BC).
Parameters used for evaluation and comparison are as follows:

Pulp temperature;
ºBrix;
Pressure (Firmness of Pulp); and,
Tit Titratable Acids (TA).

Comparison Pulp Temperature - CAT1 – 80

Table 5 shows the application of the TODIM data comparison method, presenting the gains and losses, Temperature of the pulp fruits CAT1 – 80.
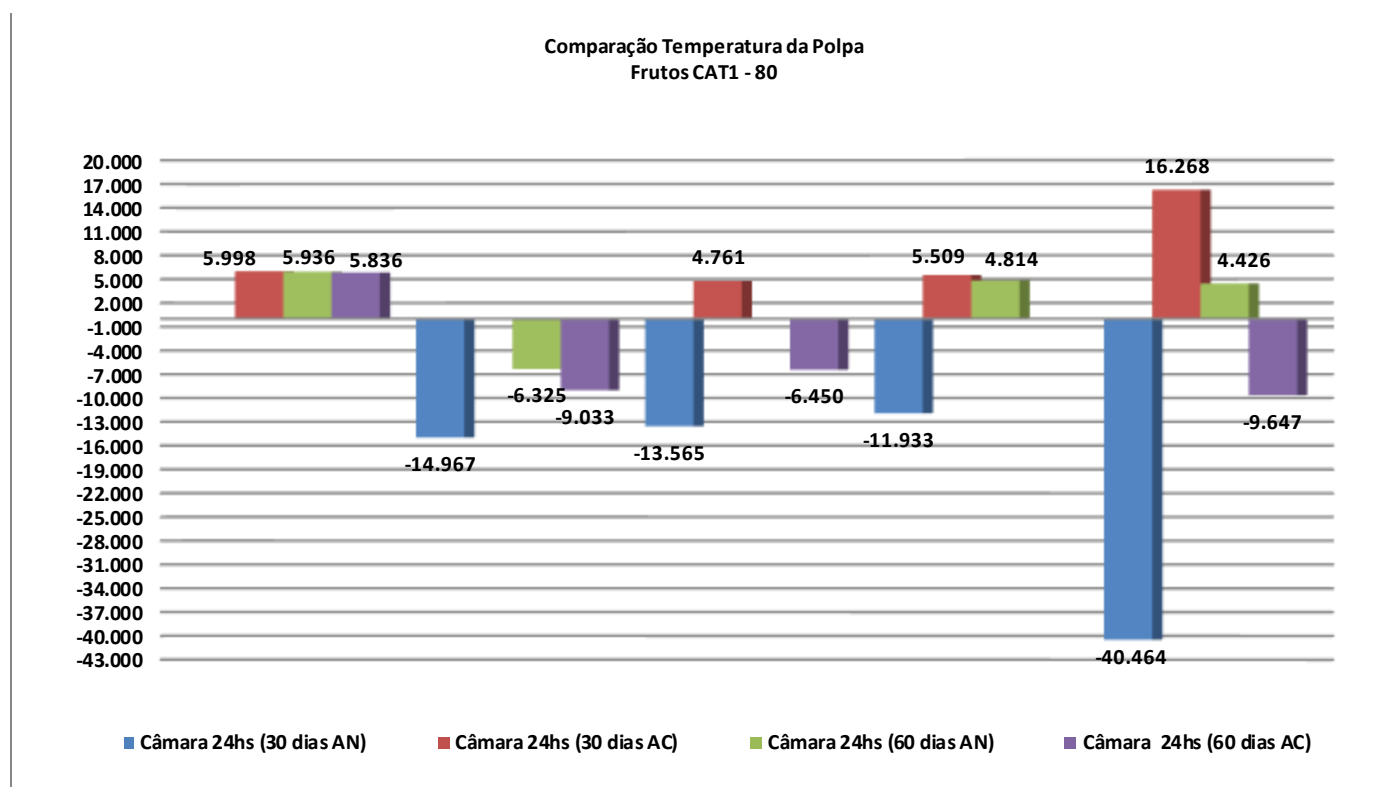
Fig.10: Temperature Comparison of Fruit Pulp CAT1 - 80

It was compared the temperature of the pulp between the treatments of 30 and 60 days NA and CA, it was concluded with the application of the TODIM method that the best treatment was Chamber 24hs (30 days CA) where it showed a gain of 16,268 as shown in table 12.

Comparison ºBrix - Fruits CAT1 – 80

Table 6 shows the data already applied to the TODIM Method, presenting the gains and losses, ºBrix fruits CAT1 - 80.
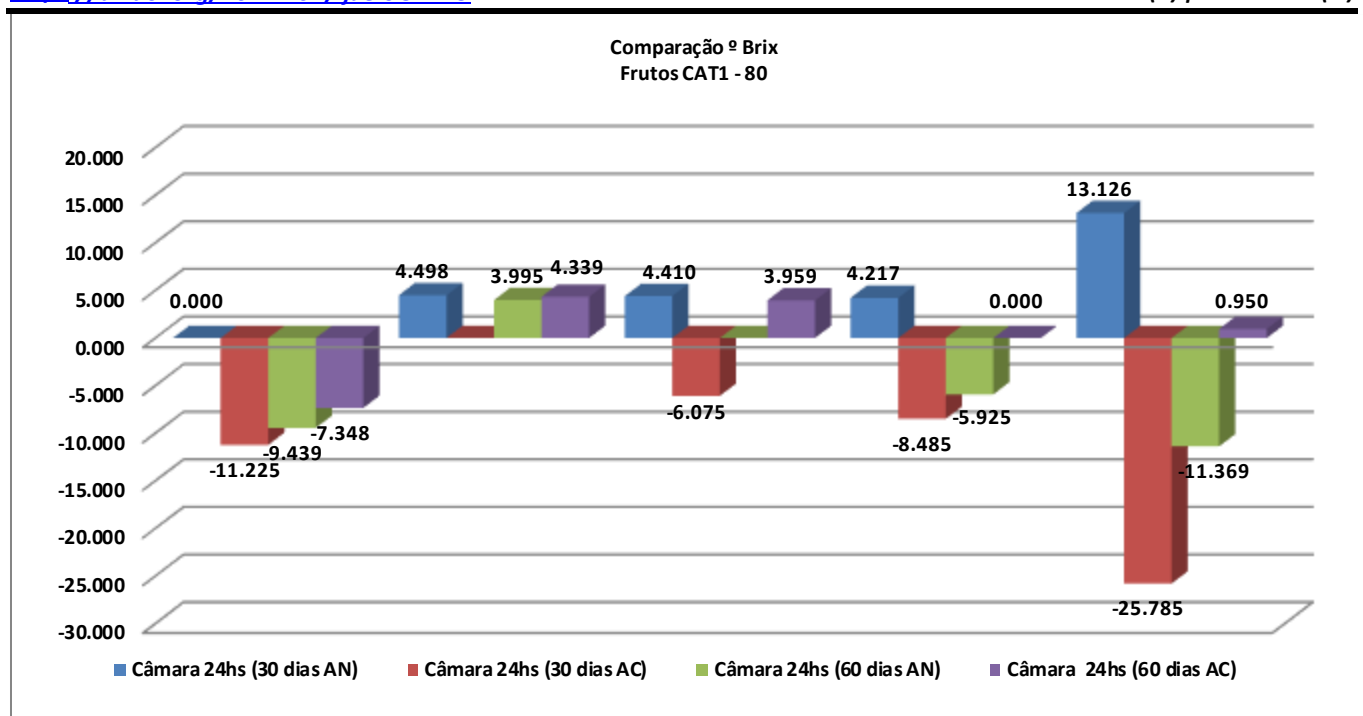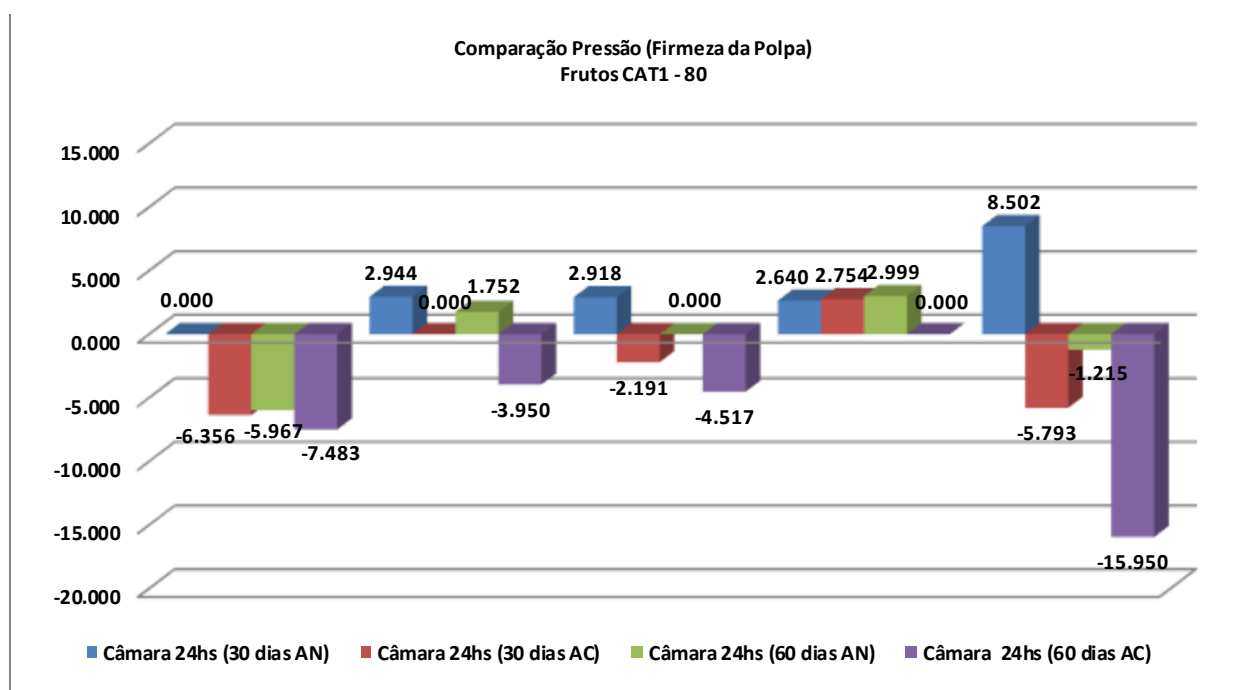
Fig.11: Comparison ºBrix - FruitsCAT1 - 80

It was compared the ºBrix between treatments of 30 and 60 days NA and CA, it was concluded with the application of the TODIM method that the best treatment was Chamber 24hs (30 days NA) where it showed a gain of 13,126 as presented in table 13.

Comparison Pressure (Firmness of Pulp) Fruits CAT1 – 80

Table 7 shows the data already applied the TODIM Method, presenting the gains and losses, Pressure (Firmness of the Pulp) fruits CAT1 - 80.

Fig.12: Comparison Pressure (Firmness of Pulp) - FruitsCAT1 - 80

It was compared the pressure (firmness of the pulp) between treatments of 30 and 60 days NA and CA, it was concluded with the application of the TODIM method that the best treatment was Chamber 24hs (30 days NA) where

it showed a gain of 8,502 as presented in table 14.

Comparison Titratable Acidity–CAT1 - 80

O quadro 8 apresenta os dados já aplicado o Método

TODIM, apresentando os ganhos e perdas, Acidez Titulável (AT) frutos CAT1 – 80.
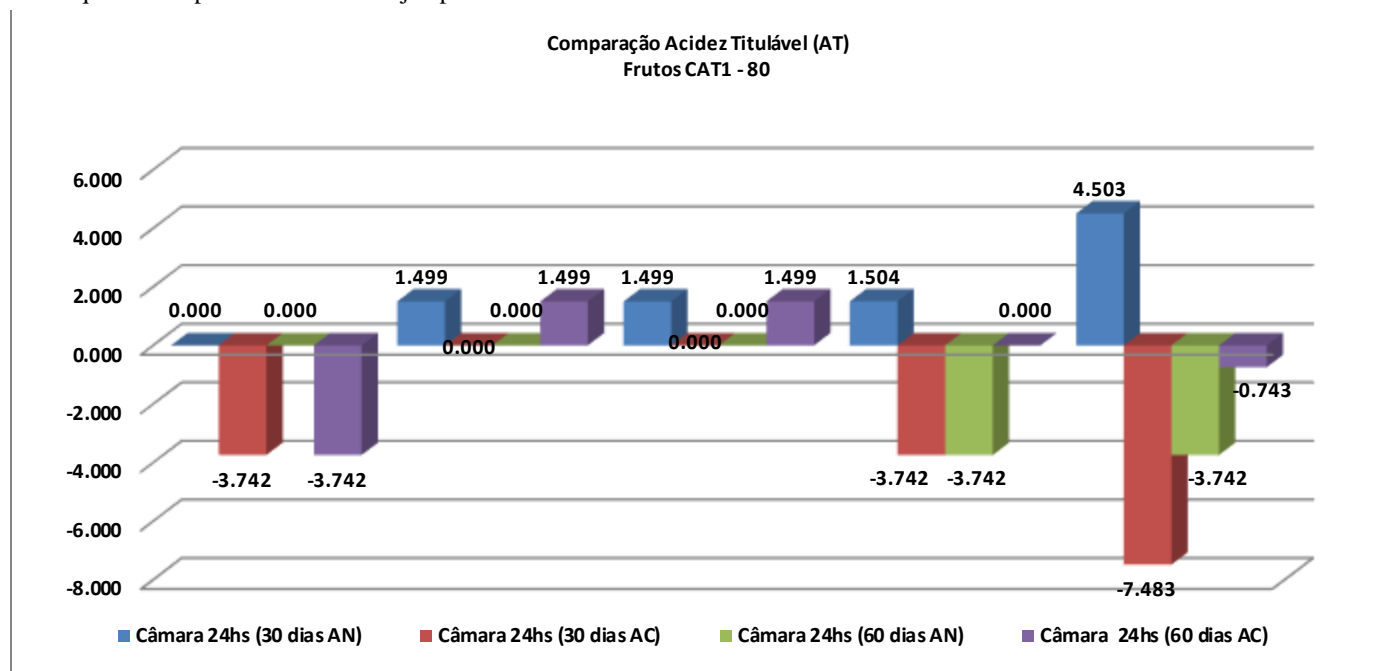

Fig.13: Comparação Acidez Titulável (AT) - Frutos CAT1 - 80

Fonte: Dados da pesquisa

In the comparison of titratable acidity (TA) between the treatments of 30 and 60 days NA and CA, it was concluded with the application of the TODIM method that the best treatment was Chamber 24hs (30 days NA) where it showed a gain of 4.503 as presented in the table 15.

Comparison Pulp Temperature - CAT1 – 198

Table 9 shows the data already applied to the TODIM Method, presenting the gains and losses, Temperature of the pulp fruits CAT1 - 198.
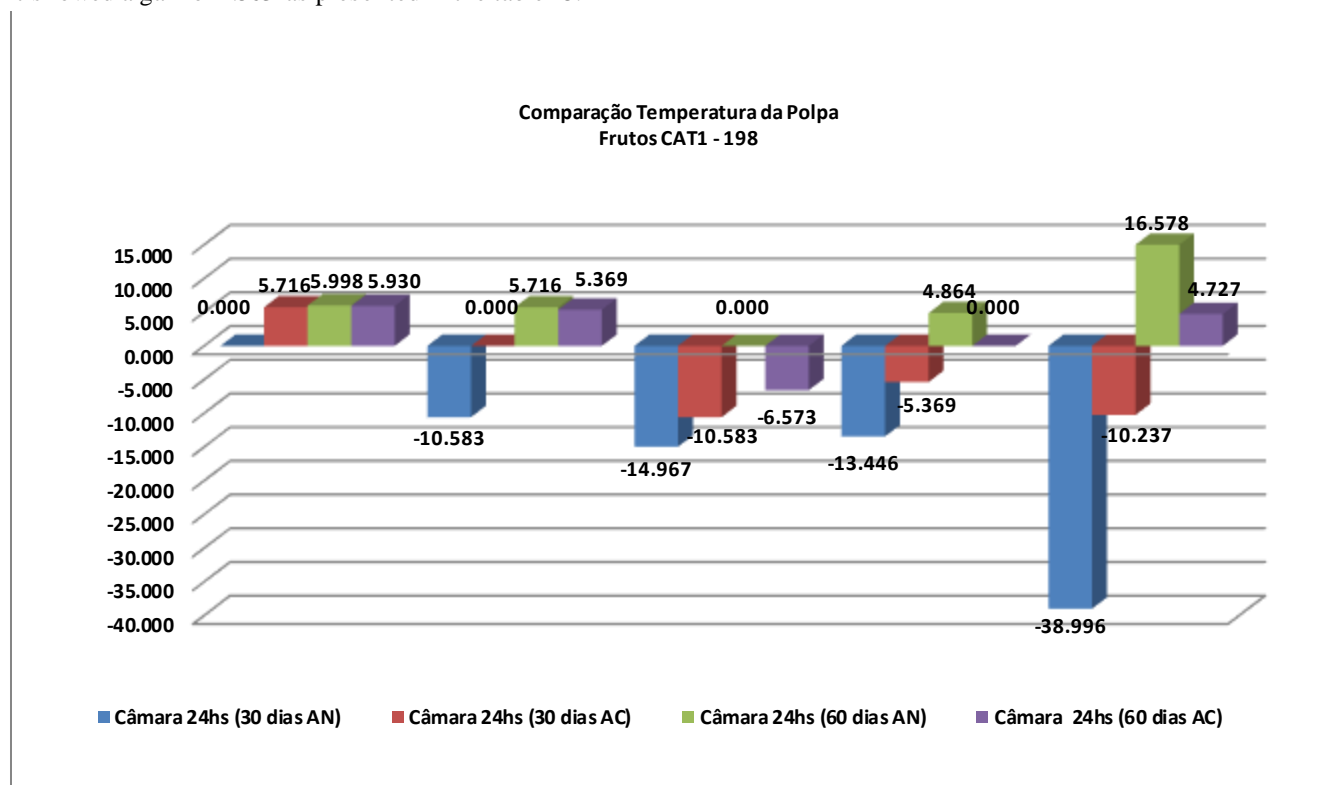

Fig.14: Temperature Comparison of Fruit PulpCAT1 - 198

The comparison of the pulp temperature between the treatments of 30 and 60 days NA and CA, was concluded with the application of the TODIM method that the best treatment was Chamber 24hs (60 days NA) showing a gain of 16,578 as presented in table 10.

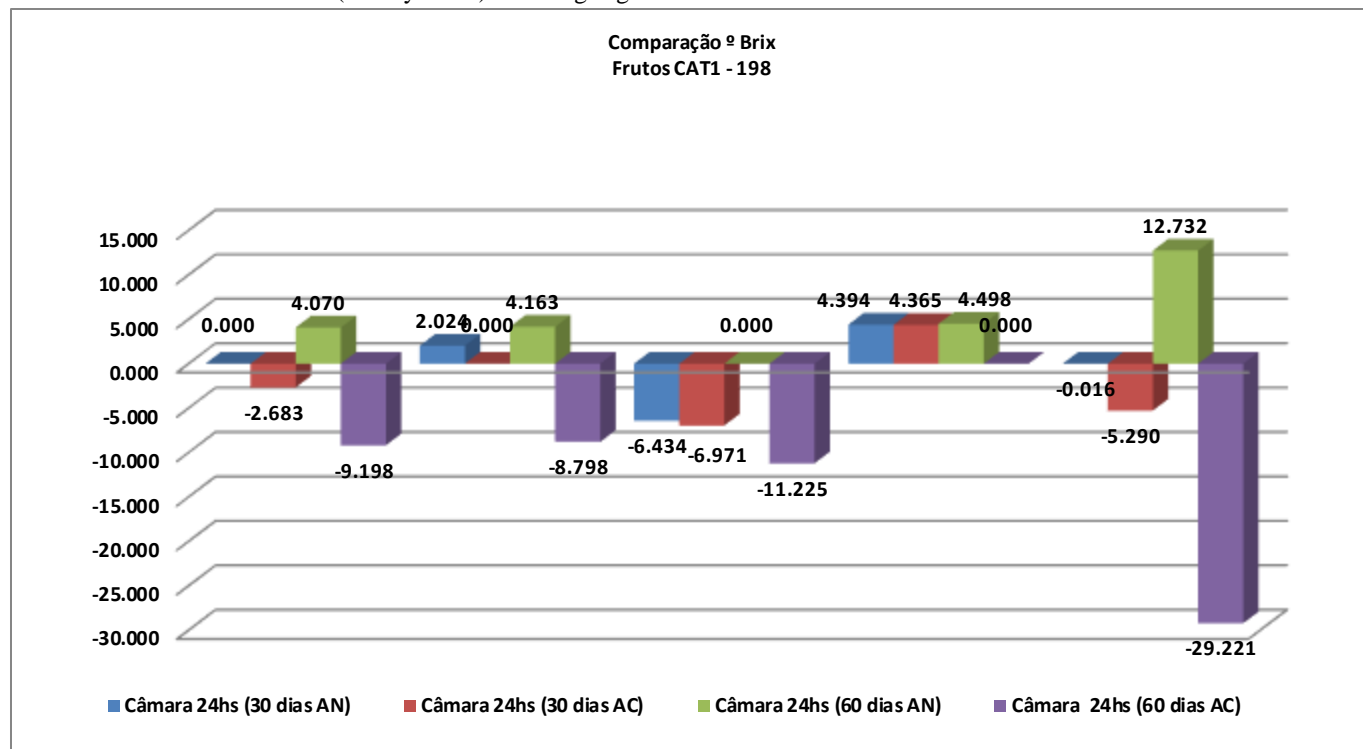**Comparação ºBrix - Frutos CAT1 – 198**

Fig.15: Comparação ºBrix - Frutos CAT1 - 198

It was compared the Brix between treatments of 30 and 60 days NA and CA, it was concluded with the application ofthe TODIM method that the best treatment was Camera 24hs (60 daysNA) where it showed a gainof 12,732 as shown in table 11.
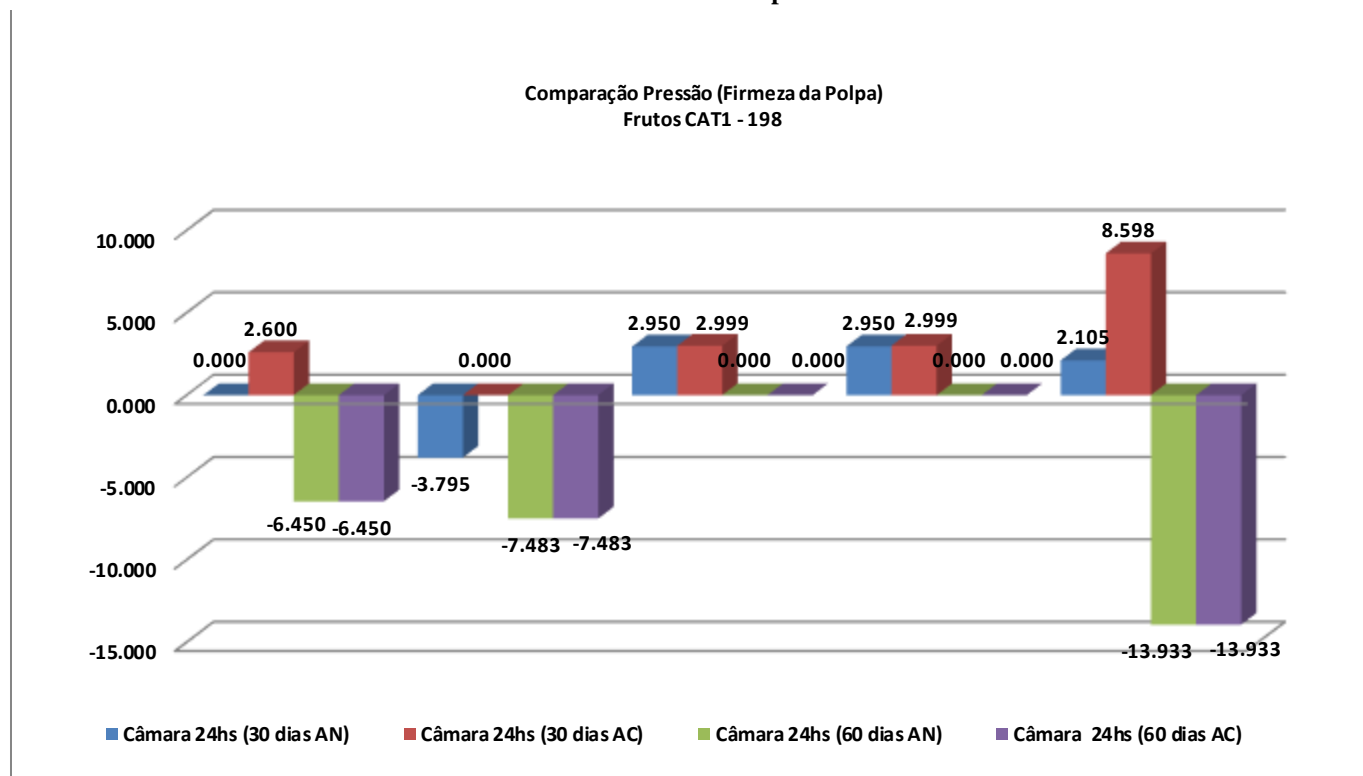
ComparisonPressureCAT1 - 198

Fig.16: Comparison Pressure (Firmness of Pulp) - Frutos CAT1 – 198

It was compared the pressure (firmness of the pulp) between treatments of 30 and 60 days NA and CA, it was concluded with the application of the TODIM method that

the best treatment was Chamber 24hs (30 days CA) where it showed a gain of 8,598 as presented in table 12.

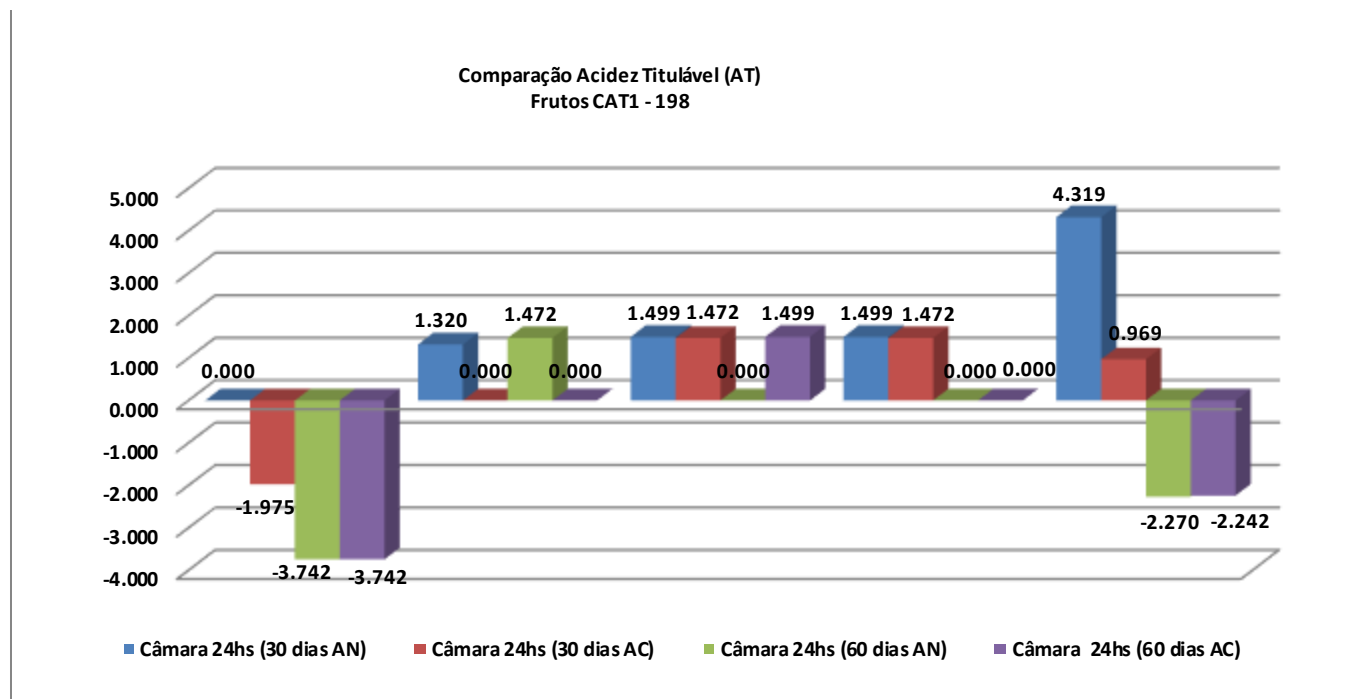ComparisonTitratableAcidity(AT) CAT1 - 198

Fig.17: Comparison Titratable Acidity (AT) - Fruits CAT1 – 80

A titratable acidity (TA) was compared between the treatments of 30 and 60 days NA and CA, it was concluded with the application of the TODIM method that the best treatment was Chamber 24hs (30 days NA) where it showed a gain of 4,319 as presented in the table 12.

III.   CONCLUSION

The question raised at the beginning of this research was: How do we use the pre-cooling and storage processes to maintain the quality of the Fuji apple (*Malus Communis*)? The answer to the research question, based on the scope adopted is as follows:

The aim of this research was to analyze how the TODIM Method of Multicriteria Decision Support contributes to the precooling process in a fast system to the cold water by immersion in relation to the forced air precooling method to maintain the quality of the Fuji apple (*Malus Commun*is).

The methodology was structured in four steps: definition of the study scenario, description of the research in the different conditions in the pre-cooling and storage processes, presentation of the results of the research in the proposed scenario and comparison of results between processes and precooling and storage using multicriteria modeling - AMD, Method - TODIM. The application of this methodology to the hypothetical

scenario made possible the analysis of the involved processes.

With this analysis it was possible to perform the data collection of the treatments involved and to obtain the results for the comparison between the processes.

In the field research carried out at the Cooperserra cooperative, the following results were identified: (1) feasibility of the implantation of the rapid precooling process to the hydrocooling by immersion proving to be efficient in the application of the system, in relation to the precooling for forced-air cooling in the chamber combined with storage; (2) the management of the Cold Chain (CC) logistic process in the pre-cooling and storage stages maintains the quality of the Fuji apple (Malus Communis).

In addition to contributing to academic research in the areas of logistics and fruit growing, the research corroborated the development of best practices in the management of the Cold Chain (CC) logistics process and commercialization, providing elements for companies to plan logistics processes incorporating the stages of pre-cooling and storage of fujiapple (*Malus Communis*).

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