# Assessing the Impact of Pumpkins Plantation, Harvest and Storage Decisions on a Collaborative Supply Chain with Data Analysis Tools

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**Abstract.** Successful pumpkins production requires the use of varieties that jointly with other factors yield well and produce pumpkins of the size, shape, color, and quality demanded by the market. But not only these issues are important. The perishable nature of pumpkins makes other issues such as how to prevent deterioration after harvest to become also relevant. In this paper the pumpkins plantation, harvest and storage (PHS) process is described and how some decisions affect certain goals, such as yield or conservation time. Additionally, some decision-making insights in a supply chain collaborative scenario made up of two stages: plantation/harvest and storage are given, where yield and conservation time trade-offs are outlined to develop win-win strategies. A real case using data analysis tools is analyzed. Results provide guidelines not only to make decisions independently on each stage but also to collaboratively work.

**Keywords:** Pumpkins, Plantation Harvest and Storage Process, Collaborative Decision-Making, Yield-Conservation Time Tradeoff, Data Analysis Tools.

## 1 Introduction

The term agri-food supply chain (ASC) has been associated to describe the activities from production to distribution that bring agricultural or horticultural products from the farm to the folk [1]. One of these ASC´s is the pumpkins SC. Different activities throughout this SC are carried out by different actors (producers, processors and distributors) from upstream to downstream.

This paper focuses on upstream the pumpkins SC and particularly in the plantation, harvest and storage (PHP) process. Later, pumpkins would be processed or just distributed to the market.

PHP decision-making is not an easy task, since some peculiar issues (that differentiate it from other types of SC´s) must be considered [2] such as the limited pumpkins shelf-life and the importance that consumers give to aspects such as quality, size and health.

Other inherent characteristics are the high levels of uncertainty these ASC should face mainly due to weather unexpected variations [3].

PHP decision-making aims, among others, to optimize different objectives such as the optimization of production yield [4], some physical characteristics or some nutrients level [5]. Another important objective is the maximization of the conservation time while keeping certain levels of the former characteristics and nutrients during storage (either in a warehouse or stored when transported) [6].

Many producers only focus on maximizing yield. This may in turn have consequences not only in terms of environmental or social impacts [7], but also downstream the pumpkins SC, since conservation time during storage can be affected, especially when the time to market is high.

Literature lacks works where the compatibility of yield and conservation time maximizing strategies is analyzed [8]. While yield-maximizing policies result in higher benefits from producers side, they are not optimal in a multi-objective context where other objectives such as conservation time after must be taken into account.

This paper makes then two main contributions:

First, the pumpkins plantation, harvest and storage (PHS) process is characterized, describing the decisions that are made as well as how they affect certain objectives, such as yield or conservation time.

Secondly, some decision-making insights in a supply chain collaborative scenario made up of two stages: plantation/harvest and storage are given, where yield and conservation time trade-offs are outlined to develop win-win strategies. A real case using data analysis tools is analysed. Results provide guidelines not only to make decisions independently on each stage but also to collaboratively work.

The paper is structured as follows: In Chapter 2, a review about the main decisions, objectives and uncertainty sources that characterize the pumpkins PHS process is conducted. Chapter 3 analyzes the PHS decision-making process and how certain decisions can affect various objectives such as yield or conservation time, either from an independent or collaborative perspective, by also reviewing some works. In Chapter 4 a real two-stage SC is analysed by assessing the impact of certain specific PHS decisions on each stage and the whole SC by means of data analysis tools. Finally, in Chapter 5 some conclusions are drawn.

## 2 Pumpkins plantation, harvest and storage (PHS) process

This paper aims first to characterize the PHS decision-making process. A literature review was first conducted.

Among others, some of the consulted works were [9]-[13].

Tables 1 to 4 show what are the main decisions that are made throughout the PHS process as well as their scope, that is, which are their usual values ranges.

The PHP process was splitted into four sub-processes: pre-plantation (Table 1), plantation (Table 2), harvest (Table 3) and storage (Table 4).

**Table 1.** Main pre-plantation decisions types & scopes in the pumpkins PHS process

| Decision Types | Decision Scope |
|---|---|
| Place | Pumpkin plants grow faster in hot climates than cold ones |
| Date | Between late may and mid of july |
| Crop Type | Very rich soils with good drainage and not too soggy and with a lot of space for sprawling vines |
| Crop Temperature | Before sowing seeds the plant soil must be at least 70ºF |
| Seeds Variety | It is important to choose the right pumpkin seeds. There are many different varieties of pumpkins and each of them have different characteristics |
| Method | Seeds planted directly in the ground or transplanted |
| Compost Use | It is advisable to dig large holes and fill them with a compost mixture one week before planting. |

**Table 2.** Main plantation decisions types & scopes in the pumpkins PHS process

| Decision Types | Decision Scope |
|---|---|
| Mulching | Row covers of different materials to protect plants and to prevent insect problems must be used. They must be removed before flowering to allow pollination. |
| Fertilization | Pumpkins must be fertilized regularly. Adding fertilizer encourages healthy plant growth. A high in nitrogen formula could be used just before vines begin to run and a high in phosphorous one just before the blooming period. |
| Irrigation | Pumpkins need lots of water (at least one inch per week). The amount of water must be decreased when the pumpkins begin to grow and turn orange. Besides, watering must be removed about a week before the planned harvest. |
| Protection | If insecticides, fungicides, or herbicides must be applied against pests, it must be taken into account that bees are essential for pollination and can be killed. If necessary, an organic pesticide to rid the plants out of pests must be used. |
| Pruning | Pruning the vines may help with space and allow the plant's energy to be focused on the other vines and fruits. |
| Fruit Turning | As the fruit develops, they should be turned (with great care not to hurt the vine) to encourage an even shape. A thin board or heavy cardboard under ripening pumpkins must be placed to avoid decay and insect damage. |

**Table 3.** Main harvest decisions types & scopes in the pumpkins PHS process

| Decision Types | Decision Scope |
|---|---|
| Date | Pumpkins must be harvested when they are mature. It typically takes 95 to 120 days. The measurement of some inputs may indicate the ripening degree: dry matter, firmness, peduncle characteristics, colour and quantity of sugar. |
| Method | The fruit must be cut off the vine carefully, without tearing. A liberal amount of stem will increase the pumpkin's keeping time and prevent early rotting. |
| Curing Period | In normal conditions, pumpkins should be cured in the sun for about a week to toughen the skin. Early frost and cold rainy weather call for early harvest. If so, pumpkins must be cured for 10 days in an area with Tª between 27-29 C. |

**Table 4.** Main storage decisions types & scopes in the pumpkins PHS process

| Decision Types | Decision Scope |
|---|---|
| Washing/ Brushing | Pumpkins are usually washed and kept dry before being stored. A good practice consists in wipening them down with a weak bleach solution to discourage rot. |
| Storage Conditions | Pumpkins must be stored in a cool and dry place. They must be kept away from humidity, damp, and direct sunlight. No refrigeration is needed. Temperatures between 10 and 16 ºC are ideal. |
| Storage Type | The pumpkins can be set in a single layer on bales of hay, cardboard or wooden shelves. They can also be hanged in mesh produce sacks. They must not be stored on concrete since it leads to rot. |
| Rot Checking | Soft spots or other signs of rot must be checked from time to time. Rotting pumpkins must be thrown away, or cut and added to the compost pile. |

The main objectives to be optimized (maximized or minimized) and the uncertainty sources were also analysed [14]:

- *Objectives*: no. of fruits per seed, weight, firmness, colour, dry matter, sugar level, no. of non-sold fruits, conservation time, incomes, costs, benefits.
- *Uncertainty sources*: seeds quality, temperature, rainfall, humity, solar radiation, atmospheric CO2 concentration, soil evaporation, wind, weeds, pests, fire or flood disasters, diseases, effects of fertilization, ripening pace, agricultural machinery breakdowns, rot rate, customer demand, competitors influence.

## 3 Pumpkins PHS decision-making process in a collaborative context

Many works in the literature analyse how different goals values may considerably vary depending on the decisions made throughout the PHS process.

However, most of them face it from a non-collaborative perspective, considering two independent stages.

On the one hand a first stage made up of pre-plantation, plantation and harvest sub-processes where the main goal is to maximize yield [15]-[17]. Other goals are the optimization (max or min) of certain physical–chemical properties [18]-[19].

On the other hand a second stage made up of the storage sub-process where the conservation time (while maintaining acceptable levels of certain important properties over time) becomes the most relevant goal to be maximized ([20]-[27].

Collaborative perspective in which optimal strategies may involve a trade-off between yield and conservation time is rarely discussed [8]. Nevertheless, other trade-offs have extensively analyzed in the literature, mainly those between the yield and some environmental and social impacts (nutrient cycling, water quality, carbon emissions, soil degradation, labor workload, etc.) [28]-[30].

In this paper an approach based on data analysis tools to support decision-making in the pumpkins PHS process is developed. The obtained results will provide guidelines to make decisions in a collaborative scenario in a two-stage SC (pre-plantation, plantation and harvest sub-processes & storage sub-process) where different trade-offs between yield and conservation time will be outlined.

# 4 Real case study

## 4.1 Study area and experiments development

The study was carried out in South Britanny (France). Neighboring parcels divided into blocks were selected. Only one type of pumpkin was chosen: the orange summer, an uchiki kuri variety that has been breeded to a hybrid one to be more productive and resistant.

The different experiments were carried out in each block then, assuming almost constant soil characteristics. Besides, only 15 seeds were planted in each block.

The selected decision variables and their specific values concerning to each of the different PHS sub-processes are as follows:

1. *Pre-plantation*: date (21st week; 24th week)
2. *Plantation*: mulching types (plastic; biodegradable)
3. *Harvest*: state based on maturation degree (under maturity; optimum; controlled; over maturity), brushing (yes; no)
4. *Storage*: storage conditions (hangar; controlled conditions/fridge with a temperature of 14°C, a humidity rate by 60-75% and regular ventilation )

All the other potential variables throughout the different PHS sub-processes (expressed at the beginning of the paper) were assumed to remain constant or not subject to significant variability between the different experiments.

In a first stage, different performance parameters/characteristics of the pumpkins were analyzed after production (pre-plantation, plantation and harvest sub-processes), before being stored (storage sub-process).

- *Yield parameters*: number of commercial fruits/seed planted; Marketable weight/seed planted
- *Physical characteristics*: weight; color; stem stage; hardness with or without skin.
- *Biochemical characteristics*: sugar level; dry matter level.

Different experiments were carried out by crossing the different agreed values for the three decision variables: planting date, mulching type and harvesting state.

It must be remarked that once the seeds are planted, it is relatively easy to guess the maturation degree and therefore the harvesting date from the follow-up of some factors such as temperature or rain (until the flowering) or with the simple visualization of some physical characteristics.

In a second stage, it was aimed to analyze the performance measure “conservation time”.

This was done by storing some samples between 20-30 pumpkins from each modality, that is, considering the planting date, mulching type and the harvesting state based on the maturation degree, under two different storage types: hangar and controlled conditions (fridge). A weekly tracking allowed to analyze the pumpkins conservation time for each modality and therefore the losses (rotten pumpkins) over time of each modality.

### 4.2 Data collecting and processing

The study data was collected either in a traditional manual way or with the help of new technologies such as internet of things sensors. Then, the data was stored in several excel spreadsheet for its analysis.

The excel spreadsheets were loaded in a dataset. For that, it was previously necessary to perform a data cleaning (data conversion, missing values correction, etc.) in order to obtain a consistent dataset. Then, a dataframe was created from the dataset.

### 4.3 Experiments development and results

Regarding the first stage (pre-plantation, plantation and harvest sub-processes) it must be noted that due to a lack of data, mulching factor was kept constant (plastic). Therefore eight experiments were carried out (2 levels for “planting date” factor * 4 levels for “harvesting state” factor), resulting in eight different modalities of pumpkins. Different performance parameters/characteristics (dependent variables) were analyzed.

More specifically, a two-factor ANOVA statistic analysis (2*4) with various samples per modality was performed for each dependent variable: weight, fruits per seed, sugar, dry matter and firmness (skinless and with skin).

ANOVA analysis (99% confidence level) based on F ratio performed for each one of the previous dependent variables indicated that there were significant differences between the means obtained for the 2 levels of the “planting date” factor.

There were also significant differences between the means of the 4 levels of the “harvesting state” factor except for the dependent variable “fruits per seed”. Finally, only a significant interaction between the factors was found for the dependent variable firmness.

Further analysis based on Tukey´s HSD (honestly significant difference) test was performed to find which means were significantly different from each other for the 4 levels factor “harvesting state”.

Table 5 shows the mean, standard deviation and 99% confidence levels after ANOVA analysis. Only the dependent variables with no interaction between the factors are shown since the firmness (skinless and with skin) would require more precise analysis.

**Table 5.** Statistic parameters (mean, standard deviation and 99% confidence levels limits) after ANOVA analysis of some of the different dependent variables measured after production

| | | | Statistic parameters | | 99% confidence level limits | |
|---|---|---|---|---|---|---|
| **DEPENDENT VARIABLES** | **Factors** | **Levels** | **Mean** | **Standard deviation** | **Lower limit** | **Upper limit** |
| **WEIGHT (g)** | **Planting Date** | **21st week** | 1468 | 181,4712399 | 1333,062002 | 1602,937998 |
| | | **24th week** | 1293,222222 | 124,6775504 | 1200,514755 | 1385,92969 |
| | **Harvesting State** | **Under maturity** | 1304,222222 | 139,1170932 | 1200,77783 | 1407,666614 |
| | | **Optimum** | 1534,611111 | 252,9806437 | 1346,500303 | 1722,72192 |
| | | **Controlled** | 1291,488889 | 102,4285608 | 1215,325278 | 1367,6525 |
| | | **Over maturity** | 1392,122222 | 65,63812465 | 1343,315165 | 1440,929279 |
| **FRUITS PER SEED (nº)** | **Planting Date** | **21st week** | 2,655555556 | 0,390631018 | 2,365090975 | 2,946020137 |
| | | **24th week** | 1,083333333 | 0,256038192 | 0,892949 | 1,273717667 |
| **SUGAR (ºbrix)** | **Planting Date** | **21st week** | 7,6 | 1,544491679 | 6,866631577 | 8,333368423 |
| | | **24th week** | 10,58333333 | 1,062159036 | 10,07899012 | 11,08767655 |
| | **Harvesting State** | **Under maturity** | 7,566666667 | 2,525162261 | 5,870998287 | 9,262335047 |
| | | **Optimum** | 9,133333333 | 1,724077853 | 7,975600088 | 10,29106658 |
| | | **Controlled** | 9,244444444 | 1,200493726 | 8,438302486 | 10,0505864 |
| | | **Over maturity** | 10,42222222 | 1,635531401 | 9,323948688 | 11,52049576 |
| **DRY MATTER (%)** | **Planting Date** | **21st week** | 11,83333333 | 2,223156369 | 10,18024345 | 13,48642321 |
| | | **24th week** | 18,18333333 | 2,763671252 | 16,12832855 | 20,23833812 |
| | **Harvesting State** | **Under maturity** | 15,56666667 | 4,830596927 | 11,97474169 | 19,15859164 |
| | | **Optimum** | 17,78333333 | 3,307214336 | 15,32416194 | 20,24250473 |
| | | **Controlled** | 13,7 | 4,097316195 | 10,65332635 | 16,74667365 |
| | | **Over maturity** | 12,98333333 | 2,900632115 | 10,82648748 | 15,14017919 |

The main insights were the following:

- F ratio from ANOVA indicated that planting date has an influence over the weight, fruits per seed, sugar and dry matter. But this influence is greater for the last three dependent variables and not as much for the weight. For example the yield (fruits per seed) of planting at 21st week (start of june) rather than at 24th (end of june) results in a mean deviation of 1.5 fruits per seed aprox.
- F ratio from ANOVA indicated that harvesting state has an influence over the weight, sugar and dry matter. Further Tukey´s test indicates that: for the weight there is a slight significant variation between the means of the levels "optimum" and "controlled" (250 g. aprox.); for the sugar there is a significant variation between the means of the level "under maturity" with respect "optimum", "controlled" and "over maturity" (2º brix aprox.); for the dry matter there is a significant variation between the means of the level "optimum" with respect "controlled" and "over maturity" (4,5% aprox.).

Regarding the second stage (storage sub-process) it must be also noted that, similarly to the first stage, a lack of data led to not to consider the brushing variable. This simplification led to just check the storage conditions (hangar, controlled conditions/fridge) over the former 8 modalities. A weekly tracking allowed to analyze the "conservation time" of the different samples of pumpkins.

As in the first stage, a two-factor ANOVA analysis (8*2) with various samples per group was performed for the dependent variable conservation time. ANOVA analysis (99% confidence level) based on F ratio indicated that there were significant differences either between some of the means obtained for the 8 levels of the "modality" factor or the means for the 2 levels of the "storage conditions" factor. But in this case, a significant interaction between the factors existed.

It led to separately analyze the simple effects in an attempt to maintain the essential structure of the interaction effect. The approach consisted in breaking the interaction effect into component parts and then tested the separate parts for significance (Tables 6 to 7). Since multiple test were performed, some significance level adjustments were applied, dividing the current one (0,01%) by the number of simple effects tests performed within each factor [31].

**Table 6.** Statistic parameters (mean and standard deviation) after ANOVA analysis to test effect of storage conditions over each modality.

| | | | Statistic parameters | |
|---|---|---|---|---|
| DEPENDENT VARIABLE | Modality factor | Storage Conditions factor | Mean | Standard deviation |
| CONSERVATION TIME (weeks) | $21^{st}$ week -under maturity | hangar | 18,6 | 2,357672727 |
| | | fridge | 31,7 | 8,116182218 |
| | $21^{st}$ week -optimum | hangar | 19,4 | 4,404543109 |
| | | fridge | 29,06666667 | 5,391351098 |
| | $21^{st}$ week -controlled | hangar | 16,06666667 | 3,321127076 |
| | | fridge | 18,3 | 4,526930908 |
| | $21^{st}$ week -over maturity | hangar | 13,4 | 3,317664322 |
| | | fridge | 15,2 | 5,155512617 |
| | $24^{th}$ week-optimum | hangar | 19,86666667 | 3,540244813 |
| | | fridge | 25,4 | 5,424084223 |
| | $24^{th}$ week-optimum | hangar | 20,33333333 | 5,208304598 |
| | | fridge | 22,4 | 4,406891155 |
| | $24^{th}$ week-controlled | hangar | 15,83333333 | 4,698373404 |
| | | fridge | 17,66666667 | 5,83292281 |
| | $24^{th}$ week-over maturity | hangar | 15,23333333 | 4,352433591 |
| | | fridge | 14,7 | 4,340268544 |

**Table 7.** Statistic parameters (mean and standard deviation) after ANOVA analysis to test effect of modality over each storage condition.

| | | | Statistic parameters | |
|---|---|---|---|---|
| DEPENDENT VARIABLE | Storage Conditions factor | Modality factor | Mean | Standard deviation |
| CONSERVATION TIME (weeks) | hangar | $21^{st}$ week -under maturity | 18,6 | 2,357672727 |
| | | $21^{st}$ week -optimum | 19,4 | 3,74718285 |
| | | $21^{st}$ week -controlled | 16,06666667 | 3,321127076 |
| | | $21^{st}$ week -over maturity | 13,4 | 3,317664322 |
| | | $24^{th}$ week-under maturity | 19,86666667 | 3,540244813 |
| | | $24^{th}$ week-optimum | 20,33333333 | 5,208304598 |
| | | $24^{th}$ week-controlled | 15,83333333 | 4,698373404 |
| | | $24^{th}$ week-over maturity | 15,23333333 | 4,352433591 |
| | fridge | $21^{st}$ week -under maturity | 31,7 | 8,116182218 |
| | | $21^{st}$ week -optimum | 29,06666667 | 6,736075463 |
| | | $21^{st}$ week -controlled | 18,3 | 4,526930908 |
| | | $21^{st}$ week -over maturity | 15,2 | 5,155512617 |
| | | $24^{th}$ week-under maturity | 25,4 | 5,424084223 |
| | | $24^{th}$ week-optimum | 22,4 | 4,406891155 |
| | | $24^{th}$ week-controlled | 17,66666667 | 5,83292281 |
| | | $24^{th}$ week-over maturity | 14,7 | 4,340268544 |

The main insights were the following:

- F-ratio from the various ANOVA analysis to separately test the effect of storage conditions over the different modality levels resulted in significant mean variations only for the modalities 21st week-under maturity, 21st week-optimum and 24th week-under maturity, and mainly the first one (13 weeks gap aprox.)
- F-ratio from the various ANOVA analysis to separately test the effect of modality over the different storage conditions levels resulted in significant

mean variations either for the hangar or fridge levels. Further analysis based on Tukey´s HSD test was performed to find which means were significantly different from each other for the 8 modality levels.

- HSD scored 3,562 for the case of hangar level, so that significant mean variations were found between:
  - 24th week-optimum with respect to 21st week-controlled, 21st week-over maturity, 24th week-controlled and 24th week-over maturity.
  - 24th week-under maturity with respect to 21st week-controlled, 21st week-over maturity, 24th week-controlled and 24th week-over maturity.
  - 21st week-optimum with respect to 21st week-over maturity, 24th week-controlled and 24th week-over maturity.
  - 21st week-under maturity with respect to 21st week- over maturity
- HSD scored 5,194 for the case of fridge level, so that significant mean variations were found between:
  - 21st week-under maturity with respect to 21st week-controlled, 21st week-over maturity, 24th week-under maturity, 24th week-optimum, 24th week-controlled and 24th week-over maturity.
  - 21st week-optimum with respect to 21st week-controlled, 21st week-over maturity, 24th week-under maturity, 24th week-optimum, 24th week-controlled and 24th week-over maturity.
  - 24th week-under maturity with respect to 21st week-controlled, 21st week-over maturity, 24th week-optimum, 24th week-controlled and 24th week-over maturity.
  - 24th week-optimum with respect to 21st week-over maturity and 24th week-over maturity.

This statistic analysis in both stages can be used as an aid for SC collaborative decision-making, so that different trade-offs between yield and conservation time can be easily computed and therefore implemented (see Fig.1 and Table 8).

Fig. 1 depicts how the losses were over time for the various modalities under different storage conditions. Only the first 28 weeks were represented.

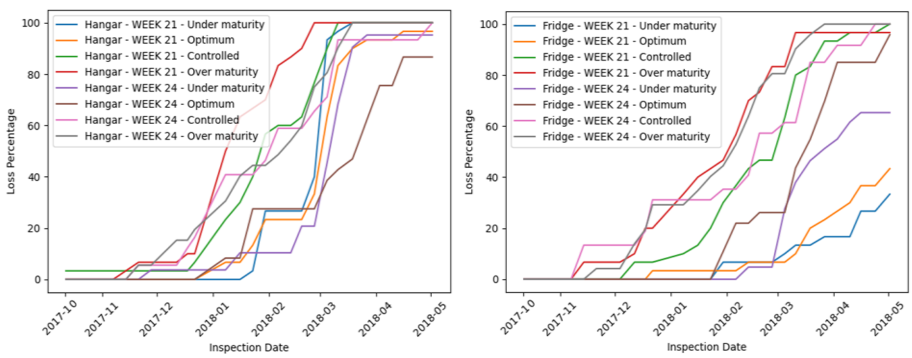


**Fig. 1.** Loss percentage over time of the different “modalities” varying storage conditions

Table 8 shows the different trade-offs for the various modalities. Each modality has a different yield (only dependent of the planting date) and a loss percentage (25%, 50%, 75% and 100%) over time depending on the storage conditions: hangar or fridge. It must be noted that some modalities under certain storage conditions were not completely lost over the 28 weeks tracking time, so that only the loss percentage at that time is indicated.

**Table 8.** Yield & Conservation time (% losses over time) of the various modalities

| 1st stage (pre-plantation,plantation, harvest) | | 2nd stage (storage) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Modalities | YIELD (no.fruits per seed) | % LOSSES OVER TIME (weeks) - Hangar | | | | % LOSSES OVER TIME (weeks) - Fridge | | | |
| | | 25% | 50% | 75% | 100% | 25% | 50% | 75% | 100% |
| WEEK 21-Under Maturity | 2,65 | 15 | 19 | 20 | 22 | 27 | 28 (30%) | | |
| WEEK 21-Optimum | | 15,5 | 19,5 | 21 | 28 (95%) | 24 | 28 (40%) | | |
| WEEK 21-Controlled | | 13 | 15 | 19 | 20,5 | 15 | 19 | 21 | 28 |
| WEEK 21-Over Maturity | | 10,5 | 12 | 15 | 18,5 | 11,5 | 16 | 18 | 28 (95%) |
| WEEK 24-Under Maturity | 1,08 | 20 | 21 | 22 | 28 (93%) | 20 | 22,5 | 28 (65%) | |
| WEEK 24-Optimum | | 13,5 | 23 | 24 | 28 (85%) | 18 | 21,5 | 23 | 28 (95%) |
| WEEK 24-Controlled | | 10,5 | 16 | 20,5 | 28 | 10 | 18 | 22 | 26,5 |
| WEEK 24-Over Maturity | | 12 | 17,5 | 21 | 22 | 10 | 16 | 18 | 22,5 |

Some insights from Fig. 1 and Table 8 could be drawn:

- Harvesting states "under maturity" and "optimum" had a reasonable conservation time for storage condition "hangar". However those whose planting date was in the week 24 (higher yields) had even higher conservation times.
- Losses over time, as it could be predicted, were lower for storage condition "fridge". However the maximum variation between "hangar" and "fridge" is given for those whose planting date was in the week 21, mainly for harvesting states "under maturity" and "optimum". No rotten pumpkin after 24-27 weeks stored and 60-70% marketable after 28 weeks.

Different trade-offs between yield and conservation are then outlined. Decision-making in a collaborative scenario will select the most profitable for the SC as a whole. Nevertheless, other factors will have to be considered such as time to market after harvest, targeted quality of pumpkins, sustainable issues (environmental and social impacts) as well as the cost of implementing the different decisions.

It must be finally noted the absence in this paper of knowing how certain relevant characteristics (biochemical or physical) evolve during storage, and therefore meet the customers quality requirements when marketed. This would require a more precise analysis.

## 5 Conclusions

Two main contributions are made in this paper:

First, the pumpkins plantation, harvest and storage (PHS) process was characterized, describing the decisions and their usual scopes in each of the different sub-processes. Later, with the use of data analysis tools, the effect of some of these decisions (with specific scopes) over certain objectives throughout the PHS process such as physical and biochemical characteristics, yield or conservation time was checked.

Secondly, and taking advantage of the first contribution, some decision-making insights in a collaborative real two-stage pumpkins SC were pointed out. Some trade-offs were outlined between the yield (plantation and harvest 1st stage) and conservation time (storage 2nd stage) to develop win-win strategies.

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