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# THE CHANGE OF SUGAR CONTENT AND FLESH CONSISTENCY OF APPLE DURING STORING, AND TRENDS OF APPLE CONSUMPTION

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Fruit production

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# 1. INTRODUCTION

Apple is one of the most consumed and produced fruit in the world. Its popularity goes beyond generations, and it is one of the most common food items. It appears in the history, in different cultures and religions. Apple is a symbol of several things such as the wholeness and unity. Production of apple is a key sector of developed temperate zone countries' agriculture. The number of produced cultivars also resembles the generality of apple. Farmers are required to keep the space of the demand and produce as much and as good apple as it is required. In some countries it is happening in more centralised way by subsidies and programs. While in other countries farmers have a harder life to survive. What is more the demand of apple is also different. Some people are looking for apple that is either sweet or sour, so the flavour is considered. While some others are keeping an eye on the colour and the overall outlook of the apple before purchasing. Usually, price is an important factor no matter what. Where apple is produced, in those countries it is considered as a cheaper option of fruit, whereas in areas where it is not a common thing on the shelfs the price could be quite high. Even in producer countries it could be expensive depending on the taxes, because somewhere fruits are tax free while for example in Hungary fruits have a 27% tax rate. Another price increasing factor could be the particular cultivar of apple, due to the club cultivars. Club cultivars such as 'Pink Lady' or 'Evelina' are cultivars which rights are reserved by a company. It is up to them who can produce those cultivars, and every further process is followed and organised by them.

Cultivars can become popular and can be forgotten, the preferences could change but the characteristic parameters are constant. That is why these factors are observed when the apple is under control. These could be the flesh firmness, the sugar concentration (Brix value), starch index, colour of exocarp, the concentration of vitamins, nutrients, particles etc… In this research the aim was to observe the changes that are occurring during storage. More specifically, the changes in flesh firmness and sugar concentration. In addition, an organoleptic test was carried out as well to judge the flavour and consistency of the apple in a more down to earth way. In the experiment the following cultivars were used: 'Granny Smith', 'Jonagold', 'Idared', 'Karneol' and 'Rodonit'. These cultivars were chosen because of several reasons. The first three are quite famous in Hungary and all are classical, preferred cultivars and massive players on the market. The other two, so 'Karneol' and 'Rodonit' are new cultivars and considered as resistant cultivars which means that these ones are more adapted to today's conditions by showing full or partial immunity against some key pests and diseases, that is a big positive attribute in farmers' eyes. Apple inner characteristics are something that people consider a lot when they purchase the fruit, whereas it is kind of like a surprise until the first bite. So, farmers must make sure that the fruit inside is exactly what is claimed about it, otherwise consumers will feel that they have been tricked.

However, it is one side of the story what kind of apple can the farmer show up. On the other hand, it is very important and useful to know that what are the demands by the customers. What trends are the most common in apple consumption. It would be a waste of money and not feasible at all to produce any crop that is not possible to sell because buyers are not prefer it. That is why, discovering the needs and demands is crucial. A part of this thesis is trying to introduce the current trends of apple consumption in Hungary and beyond, with a help of a survey that was created for this purpose. In several questions the goal was to get an overview of people's apple choice and what are their preferences in taste, flavour, consistency, price etc... How strong is the consumer awareness. Overall, (in Hungary definitely) the apple eaters are quite conservative about what kind of apple to buy. Older generations are still looking for cultivars that they are comparing with their childhood. However, nothing is constant neither the range of apple cultivars which are available on the market. Moreover, keeping in my new names of cultivars is a bit challenging and it is way easier to say that "I'm looking for that sharpy one" or "Do you have that soft type?". Despite different costumer behaviours there are some cultivars that are well recognisable by everyone like "Granny Smith" that won its popularity by its unique appearance. In the following thesis the goal is to introduce the observation of the inner quality of five selected cultivars by measuring their flesh firmness and sugar concentration and to see that what are the preferences of the customers in the recent years.

## 2. OBJECTIVES

The research was made to answer the following questions. These questions were the guidelines of the research. Each of the five cultivars were examined separately. The questions were about whether there is a significant difference between means of the flesh firmness and of the sugar content. The statistical analysis was happened twice as once the means of a given cultivar were compared by the different harvest dates, then the comparison was made by the different measuring dates.

An organoleptic test was prepared as well. In this case no statistical analysis were made as this test is based on taste preferences of the three judges who have evaluated the cultivars based on flavour and consistency.

# 3. LITERATURE REVIEW

## BIOLOGY OF APPLE

Apple is clearly the most important and common temperate zone fruit to be produced and consumed. It is belonging to the Malus genus, that is belonged to the Rosaceae family. The chromosome number of Malus spp. is 17. The majority of the species are either diploid or triploid. (O'Rourke, D., 2021) The origin of the consumed species is from Central Asia, the territory of today's Kazakhstan. The cultivated apple is thanked to interspecific hybridization, that is why the general name is Malus x domestica. It is assumed that the main progenitor is the species called Malus sieversii. Although, Malus genus has several species and it is a genetically diverse genus, the cultivated apple cultivars are genetically really close to each other as majority of them is derived from Delicious and Golden Delicious. The world top produced and consumed cultivars are all related to the species Malus x domestica Borkh. (Kellerhals, M., 2009). Other Malus species might have important role in rootstock production as they might have genes that are beneficial for apple production. These genes could be for resistance against pests and diseases, hardiness, tolerance of extreme climatic conditions.

Apple trees are growing between 2 and 20 meters high. The juvenile period of self-rooted trees are 4-10 years. Whereas, in cultivation where grafted trees are planted, the unproductive period is 1-3 years. Shortening of the juvenile period is one of the main reasons, of using rootstocks. Apple is deciduous so it is adapted to survive sudden climate changes throughout the years. All the growing and phenological changes are periodically following each other and, repeated year after year. The main stages of the cycle are budburst, flowering, vegetative growth, fruit set and development termination of vegetative extension, foliage senescence and abscission, fruit ripening, and winter dormancy. (Rivero et al, 2016) The cycle includes the transition from vegetative to generative growth. As there is no yield without flowers, the amount and the quality of this organ is a key. The quantitative and qualitative fluctuation of flowering is a common phenomenon in the case of pome fruits. This is called alternation, and it should be taken into account by every producer who are having a cultivation of apple or other alternating crop. That is why orchard should be establish in a way that alternation is not affecting the income dramatically. Usually, the result is large yield with small-sized crop or minor yield with larger pieces. This biennial growing is a more severe issue in the Nordic countries where the growing season is notably shorter. (Rivero et al, 2016)

## PREVIOUS FLESH FIRMNESS MEASUREMENT(S)

There have been several researches and experiments previously regarding to flesh firmness. It is an attribute that is easily measurable meanwhile it could serve as an informative and useful property for different apple cultivars. However, flesh firmness could be modified by some several factors that are damaging the cell walls, like bruising, pushing, compressions. Firmness loss during ripening is due to cell turgor changes and integrity loss of cell wall members. The exocarp of the fruit or any kind of vegetables too, provides the permanent physical barrier against any microbial invasion, plus maintains the shape and the integrity of the crop. The exocarp's mechanical behaviour massively effects on the firmness and resistance to prevent splitting of the fruit. That is why the exocarp physical parameters are important factors during new cultivar selection to reach lower bruise susceptibility. Usually, flesh firmness tests are some kinds of puncture test, which are made on a peeled area of a given fruit. The test could happen with several kind of tools, that are either manual or semiautomatic. (Grotte et al., 2001).

One research that was made by Orosz-Tóth M. and Kincses S. and published in 2019 was observing the flesh firmness of seven different cultivars. Five of them has the resistance against Venturia inequalis (Gaia, Isaaq, Modí, Smeralda, Fujion), 1 is not resistant (Golden Reinders) and 1 (Pinova) is moderately susceptible to scab. The test was done by a penetrometer. The results had showed that the lowest firmness (in $N/cm^2$) is by Gaia. Then the results for Smeralda, Golden Reinders and Pinova were not significantly different. Isaaq's and Fuijon's firmness were also not significantly different compared to each other. The highest was for Modi with 8,82 $N/cm^2$. Furthermore, the test was carried out again in the following year. At that time every result changed, either increased or decreased. The biggest difference was produced by Gaia but as the author of the article mentioned - "This probably due to the fact that the mildew attacked the Gaia apple variety so the representative sampling could not be done." The third experiment was about the flesh firmness change over storage. The testing was

happening three times monthly. The results were clearly shouting for continuous decline throughout the storage. For instance, Fujion and Golden Reinders showed 38 and 41.1 % decrease compared to the initial measurements. (Orosz-Tóth and Kincses, 2019)

Another research had the objective of this experiment was to characterise the physical effect of fruit temperature on firmness and tensile strength readings at different times during storage. The apple cultivars in the experiment were Royal Gala (RG), ‘‘Granny Smith’’ (GS), ‘Pacific Rose™’ (PR) and ‘Cox’s Orange Pippin’ (COP). RG, GS, and PR were stored at 0°C and COP on 3°C. The apples were measured at different times as throughout the storage season starting right after harvest. It was measured after 24 hours at 20°C, or after 24 hours at 20°C followed by 24 h at the storage temperature. The aim was to compare the results at 20°C and storage temperature (0 or 3°C). It was resulted that after harvest for RG GS and COP the flesh firmness and cortical tensile data were greater at 20°C than at storage temperature. However, later on these results changed and numbers were higher at storage temperature than at 20°C. PR hadn’t got significant difference at 0°C and 20°C. (Johnston et al., 2001)

It is also important to observe that what could influence the firmness of the crop. An experiment was done to examine the effect of calcium treatment at preharvest stages at Golden delicious. The test was carried as the target apple trees received 10 spraying during the growing season. 1,2% $CaCl_2$ solution was sprayed. The control trees didn’t get any calcium treatment. At harvest the crop was separated by size as small (4-5cm) and average (6-7.5cm) diameters. The samples were stored for three weeks in perforated plastic bags as 25°C. The measurements were done at harvest and after the three weeks long storage. For the small sized, there were no notable difference at harvest between the control and the treated apples. While for the average sized there were difference. Whereas, after the storing in both sizes significant differences were observed between the control and treated samples. Each time, Calcium treated apples showed higher retention of flesh firmness. The change in percentage was around the same in the case of average sized control and treated, plus small sized control (all three resulted around 20% decrease of firmness during storage). On the other side, small sized $CaCl_2$ treated samples showed only 11% change after storage. (Siddiqui and Bangerth, 1995)

### PREVIOUS DEGREES BRIX MEASUREMENT(S)

The sweety taste of apples is normally measured by destructive inspection, that is considered as a long process, so there are reports which introduce an alternative method. The particular way is using the NIR method (near infrared) to gain a quantitative coefficient of the sugar content of apple. It turned out that it is possible to do sugar content measurements of fruit by using second derivative treatment of the NIR absorption spectrum. The process was done at room temperature, and the wavelength region of the measurement was between 680 to 1235 nm. Reflectance was calculated as the NIR energy reflected from a sample was compared with standard reference. As a reference measurement, Brix was analysed using a digital-refractometer, which determined the resolution of Brix to be 0.1%, and the measuring precision to be ~0.2%. NIR spectroscopy measurements are at least as accurate as measurements using a digital refractometer. In conclusion, the Near-Infrared (NIR) method proved effective in non-destructively analysing the sugar content of apples and apple juices, achieving a SEP value (standard error of prediction) of 0.546'Bx for apples and 0.439'Bx for apple juice, with high correlation coefficients. The determination of the first wavelength at 912 nm was crucial for accurately measuring sugar content. Establishing an accurate method for sugar content measurement in apples and apple juices through the NIR method lays the foundation for potential applications in precision farming and medical fields, with future developments anticipated for both agricultural and healthcare sectors. The compilation of a spectrum library detailing absorption bands and spectral changes is highlighted as essential for advancing the method's applicability to a broader range of fruits and organisms. (Temma, Hanamatsu and Shinoki, 2002)

Another research also was carried out to observe the Firmness and the soluble solids content (SSC) particularly in Red Fuji apples. In this case, Vis/NIR transmittance was used to come up with factors thought in online detection. The wavelength spectrum was 650-920 nm and two types of data processing were used to increase the accuracy of calibration models based on partial least square (PLS). PLS is a technique that reduces the predictors to a smaller set of uncorrelated components and performs least squares regression on these components, instead of on the original data. After the Vis/NIR test the SSC measurement from the fruit pulp

was determined after compression test, using digital refractometer. The results of the experiment showed validity to use this non-destructive technique for online detection of apple internal quality. It seems legit that PLS is a potential technique to estimate component concentrations, chemical and physical properties from their infrared spectra. (Fan et al., 2009)

An experiment from China was trying to predict apple sugar content based on spectral characteristics of apple tree leaf in different phenological phases. The target trees had three parts (base part, middle part and top part), from where leave and fruit samples were collected. The leaves were taken during growing season at the time of six important phenological phases (Flowering period, Shoot-growing Stage, fruit Setting Period, Branch shooting period, Bud differentiation stage and Defoliation period) and the leaves VIS/NIR spectra reflectance were measured. The fruits were picked at the end of the season, after defoliation. The fruit sugar content was detected using the laboratory chemical analysis method. The apple juice was measured by a handheld refractometer, then the average sugar content of each apple was calculated. The report claims that the contribution proportion to apple sugar content in tree's different growth stages can be calculated by using the spectra of leaves and used to monitor apple growth process dynamically. To sum it up, it provides a potential to produce fruit with high sugar content. (Zhang et al., 2015)

**ANY OTHER FACTOR MEASURED IN APPLE STORING BEFORE**

There have been several experiments and researches regarding apple in the last decades. For the constituent improvement, it is very important to always do researches that take field of apple production further. An experiment from Central-Poland had the goal to recognize the connection between the mineral element concentration in soil, leaves, fruitlets and fruits as well as the physiological factors of fruits at harvest by taking into account the storage ability of 'Jonagold' cultivar ('Jonagold' was used in the research). Researchers also observed the efficiency of Mg-infiltration. At harvest, internal ethylene concentration, flesh firmness, soluble solids, starch index and mean fruit weight was measured. Plus, apples were infiltrated with 0.2 M $MgCl_2$ + 0.4 M sorbitol solution, and kept at room temperature for 7 days. Additional apple samples were kept at more appropriate storing conditions for 6 months to evaluate storage quality. It was assumed from the results of this particular experiment that the coefficient of determination between mineral element concentrations in fruits and bitter pit was 65%. Moreover, it was suggested that potassium concentration is in negative correlation with the occurrence of physiological disorders. K:Ca ratio in leaves, fruitlets or fruits was rather due to the appearance of bitter pit than K or Ca concentration level separately. It was concluded as well, that the amount of bitter pit-like spots induced by infiltration with magnesium chloride might be a useful way of predicting the mineral element concentration in apples and also for storage ability estimation. (Piestrzeniewicz and Tomala, 2001)

Apple is a climacteric fruit, so during postharvest ripening is still happening. This ends up in fruit softening that reduces the storability time. It is due to ethylene compound. It is assumed that by lowering the storage temperature ethylene production slows down. Furthermore, elimination of ethylene from the storehouse extends the storage ability of all cultivars, by keeping a good flesh consistency quality. Research from Czechia was comparing five cultivars' performance during cold storage by measuring the production of ethylene and other non-volatile compounds. The signs of the compound levels were measured by the flesh firmness changes and weight loss. The samples of the five cultivars, which were Golden Delicious Reinders, Resista, Topaz, Meteor and Rubinstep, were kept in cold storage for 100 days. Carbosieve G was used as a trapping solution in the enrichment column during thermal desorption of ethylene (130°C for 2 minutes) from the enrichment column to the analytical column. The results showed significant titratable acid change in the case of all observed cultivars. The Apple varieties showed only small positive abortion in ethylene production, with only Resista and Topaz having the characteristic increment and decrement over the 100 days experiment. It is stated by the authors of the research that changes of soluble solids and organic acids are not the reason of the uncommonness that is seen in the ethylene production rates observed among the five cultivars. Soluble solids were also measured but there was no change over time and the numbers are all within the interval of 12.8° to 14.6° Brix. The main reason for weight loss is water evaporation. It is claimed in the results that water evaporation is responsible for 90% of the weight losses during storage. The observed cultivars acted differently from water loss aspect. Golden Delicious Reinders, Resista and Rubinstep lost 93 to 114 mg/day of water, while Meteor and Topaz lost only

60–65 mg/day. In the literature the thickness of the skin is discussed as a factor for decreasing evaporation and also for protection against storage diseases. (J. Goliáš, et al., 2008)

Another research, that was made in China in 2023, to compare cell wall changes in four apple cultivars, in 'Fuji' 'ENVY' 'Honeycrisp' and 'Modi'. For the test, there were selected two hard-crisp varieties 'ENVY' and 'Modi', and two loose-crisp varieties 'Fuji' and 'Honeycrisp', both which are having an excellent quality with a high value on the market. In the study, it was investigated that how the activity of hydrolytic enzymes and structural traits (related to the flesh firmness) change during fruit development. For understanding and getting a more exact overview of the changes and molecular mechanisms of the fruit growth, the expression profiles of associated enzymes and genes involved in ethylene biosynthesis during their development was analysed as well. It turned out the with the development of fruits, the sugar content of the four cultivars showed an increasing trend and the difference in maturity stage was significant. In terms of fruit firmness, the fruit flesh firmness of 'ENVY' and 'Modi' was higher than that of 'Fuji' and 'Honeycrisp', and the fruit firmness gradually declined with the development of fruit. In the study, the contents of WSP (water soluble pectin) and CSP (chelator soluble pectin) of four cultivars showed an increasing trend in the early stage of fruit development, whereas the content of ISP (ionic soluble pectin) first showed an increasing trend, followed by a decreasing trend, and finally an increasing trend once more. This study serves a wide biochemical, structural, physiological, and molecular basis for fruit softening in the given cultivars of apples. Changes in fruit cell structure and arrangement, elevated activity of cell wall hydrolytic enzymes and enhanced expression levels of cell wall hydrolase-related genes occurred with fruit development and maturity. These results suggest that the fruit firmness is decreasing under the combined effect of these previously mentioned factors. The two different type varieties differed in ISP and hemicellulose content, the activity of PL and the relative expression of Mdβ-gal, and these events may be responsible for the differences in fruit texture between the hard-crisp cultivars and the loose-crisp cultivars. (Li et al., 2023)

### APPLE RESISTANCE AND TOLERANCE

In the case of apple and other fruits a very well notable percentage of the yield goes to waste during post-harvest due to several pathogens' presence. The sensitivity of fruit predestines the seriousness of the fungal attack during storage. To prevent the fungi affections so basically the yield loss, breeders were trying to come up with solutions that decreases the level of loss but also a more sustainable way of protection. The process is called induced resistance and it could be made by several treatments.

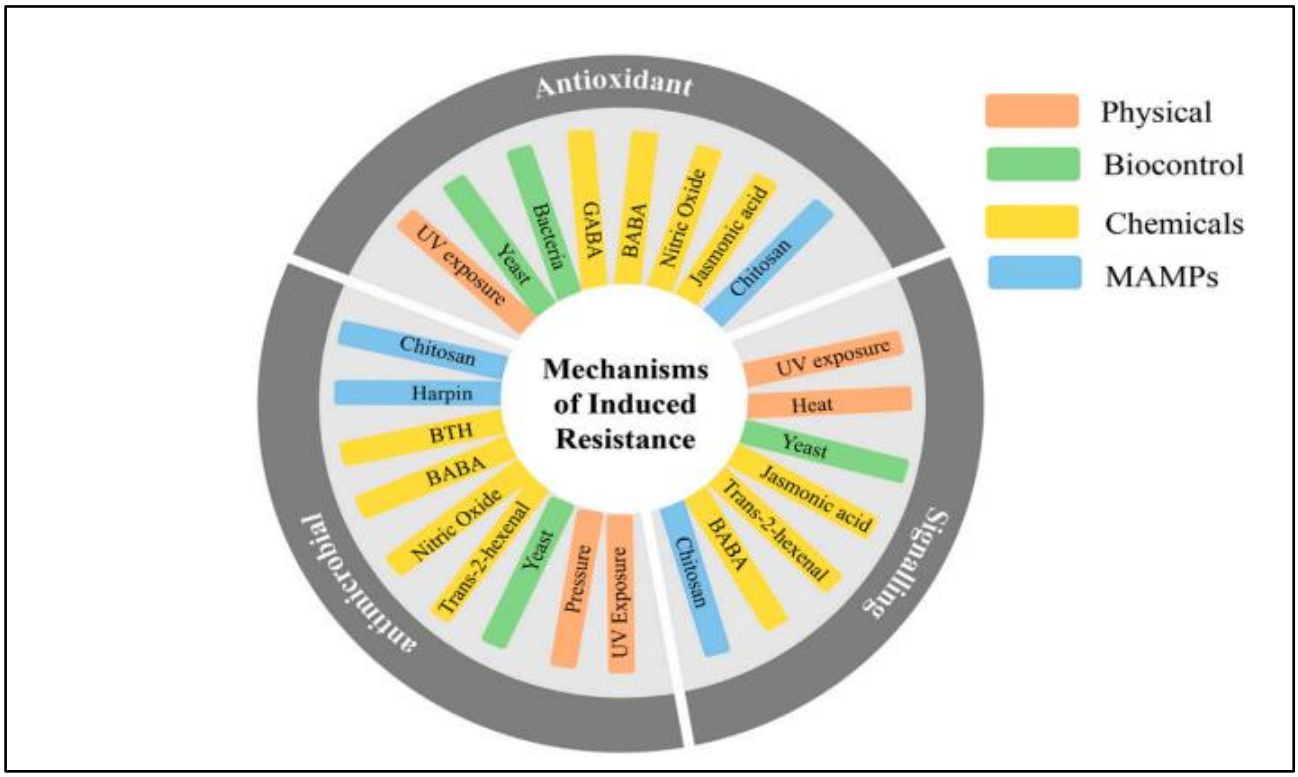


**Figure 3.2**: Methods and mechanisms of defence induction.

On figure 3.2 the methods and mechanisms of defence induction are visualised. These methods can be classified to four kinds of groups. They could be physical strategies, chemicals, biocontrol, and microbe-associated molecular patterns (MAMPs). Mechanisms are grouped in signalling functions (accumulation of pathogenesis related (PR) proteins and hormone dependent signalling), antioxidant functions (reactive oxygen species (ROS) and antioxidant enzymes), and antimicrobial functions (phenolics, lignins and antimicrobial enzymes). Induced resistance although still requires further research as it is affecting not only the crop but also the entire plant as well and it should be used together with IPM technologies and methods. Frankly, other plant processes could witness changes as a response of resistance induction. In vegetative tissue, this effect is usually represented by trade-offs in plant growth and development. This is driven by a change in the allocation of energy resources in the plants: when there is an activation of induced resistance mechanisms, plants prevent the allocation of resources to growth as they prioritize the use of energy for their survival against a threat. Other methods of induced resistance also impact plant growth due to other factors. (Pétriacq et al., 2018)

### APPLE PRODUCTION AND CONSUMPTION WORLDWIDE

Apple is the second most produced fruit behind banana. By the end of the 2010's the annual average apple production is 93 million metric tons according to Statista. The top producers are China, USA, Turkey and Poland. The greatest producer by far is China. The country covers approximately the half of the world production with around 40-45 million tons per year. This enormous amount of yield is produced on more than 2 300 hectares. The second biggest producer is the United States of America with 4,6 million tons yearly production that is produced on 130 500 hectares. The third producer is Poland with 3,6 million tons of apple in average per year on 177 000 hectares. Around the same size of area is used for apple cultivation in Turkey but there the average yield is slightly less by half million tons. The further producers by mass production are India, Iran, Italy, Russia, France and Chile. Hungary is only the twenty-fifth largest apple producer country.

From cultivation size aspect the number one position is taken by China as well. The country's apple plantation covers almost 2,4 million hectares. The second largest apple production by landmass is in India with 0,3 million hectares. The third position is taken by Iran with Iran with its 0,25 million hectares of apple cultivation. In the European Union the total area size was 460 000 hectares in 2017. The biggest areas are found in Poland Italy

and Romania. Eurostat also shows that Poland, Italy and Germany are the ones who have been establishing the most orchards in the last years.

However, it is important to mention that the previously mentioned data are for mass production and are that is used for production. If the yield (kg/hectare) is observed, the ranking of the countries show differences. In this list the podium is for Austria with 85 tons/hectare, Switzerland with 59 tons/hectare and Libya with 57 tons/hectare. Whereas, in the case of Libya the area of apple production covers around 380 hectares, so it is hard to talk about effective apple production in country level, more likely on farmer level. From the big apple producers Chile, Italy and France could make it to the top 10 from the view of yield. USA is eleventh with the average 35,5 tons/hectare average yield. The yield data is more accurate for examining the quality and level of apple production In a country. While in some countries like India and Iran the cultivation is happened on large areas the harvested yields are way below the averages of other producer countries. It can be assumed that these countries' orchards are more extensive. While in the case of Austria and Switzerland the yield is top tier quantitatively but the area that is used for production is not that much (as both countries are covered by the mountains of the Alps, this fact sounds understandable). In any case, there are some countries which are ranked highly in all aspects, so where the production is happening on a relatively large area and the average yield is absolutely high. For instance, Italy USA and Chile.

Producing apple is one thing, but the crop has to be consumed by the society. Based on Faostat the residents of the United States are eating the most apple per capita per year. An American is consuming 51,9 kg apple in a year. It means that if the produced apple in the USA is 14,1 kg per capita, then 37,8 kg of apple per capita is the amount that should be imported at least. The second largest apple eater country is Hungary with 39 kg of apple is taken per capita every year in average. In the case of Hungary in a good year no import would be needed theoretically as the produced amount would be enough to cover the necessity of apple. However, in reality is not that easy and clear, but it will be discussed in the upcoming chapter. The third largest apple consumer country per capita is Turkey, slightly behind Hungary with around 37 kg per year per capita. The bottom of the list is giving countries like Sudan, Niger and Ethiopia where a person in average eats like 0,02-0,04 kg of apple per year. This is approximately a thin slice of a medium sized apple. Obviously for these countries apple is an exotic fruit, as it is neither produced there nor commonly available.

In the previous paragraphs countries that were mentioned either as top apple producer countries or not could give the hint that why apple is common in countries like USA, Poland or China. The reason is the climate conditions of apple. Majority of the plantations can be found within the latitudes 40° and 50° in North America and Europe, 30°-40°in Asia. In the southern hemisphere between 20°and 40°. Although, production could be possible out of these zones to if it is influenced by such factors as ocean or higher elevation. In the book written by A. D. O'Rourke, it is also mentioned that apple needs a sufficient winter cold period for provoking dormancy and fruit setting in the following season. The previously mentioned zones have long warm summers that is necessary for the proper production. It is important to mention that due to the improvement of technology, recently the newly bred cultivars can be adjusted to more extreme and not that favourable conditions. Also, rootstocks are increasing the fastness against like harsh winter or drought.

It is estimated that nowadays over 30 000 apple varieties exist in the world. In reality, not more than 50 cultivars are produced commercially. The old cultivars were replaced by new from production aspect much more sufficient cultivars. That is why hundreds of cultivars can be found only in special gardens where the goal is to preserve every cultivar. From a report form 2007 it has turned out that 72% of the Entire European production is covered by 13 cultivars. The top cultivars are Golden Delicious, 'Jonagold' and Gala. These cultivars had been are broadly popular throughout the continent. Some cultivars such as 'Idared', Red delicious and Jonagored have been more common in particular countries. By 2021 there have been some minor changes. Golden delicious covers 24% of the total European apple production, followed by Gala with 9%, 'Idared' with 7%, 'Jonagold' and Red Jonaprince with 5-5%. These cultivars are representing the half of the continental apple yield. according to the article published by CBI, apple is going to stay as the most consumed fruit in Europe after banana. It is available all-year round. What is more, additional growth is expected in its consumption. Interestingly, the COVID-19 pandemic has also increased the demand for apple as the people wanted to eat

more fresh, local fruits and vegetables. Currently, a European in average is eating 15,1 kg of apple yearly. EU's apple producing area is continuously shrinking, but it cannot be seen in the yield, as the remaining orchards are highly developed and are able to have a higher yield per hectare year after year. Despite the massive production all over the continent there is and certainly there will be demand for non-European import of apple. The peak season of non-European apple import to Europe is between May and August. The highest non-European apple importers are the United Kingdom, the Netherlands and Germany.

### APPLE PRODUCTION IN HUNGARY

Apple is the most produced fruit Hungary. Its cultivation goes back to decades. Even before any orchard establishment, there were several local cultivars all around the country which were famous among the given region. Zsolt Szani in his PhD dissertation has collected 235 old cultivars with 673 different names. Based on his research the most common cultivars in the Carpathian basin were "Téli arany parmen", Batul and Jonathan. In Hungary the apple breeding had become important especially, after the II. World War. Along with the breeding, production was increasing as well. The most important region of apple is Szabolcs-Szatmár-Bereg county ever since. Famous Hungarian breeders were Aladár Porpáczy, Pál Maliga and József Budai.

Hungary's apple production is hard to assume with an average yield, as it is highly fluctuating year after year. This is due to several factors. There are hundreds of hectares of apple that are outdated, and no longer should be used. These plantations are highly influenced by the weather. Moreover, Hungarian agriculture is suffering from the lack of labour that is notable at apple producing companies too. Thirdly, it is assumed that there is lack of knowledge as well. The farmers are generally belonging to the older generations, and they might not have to required competency and motivation to establish and run intensive plantations. Not to mention that there is not enough individual from younger generation as the agriculture does not have the fame and popularity that would attract enough students to enrol in any agricultural studies, such as Horticulture. So, overall, the Hungarian fruit production is challenging numerous problems, and in reality, there is no hope that these issues will disappear in the near future. Furthermore, there are some specific problems which are occurred exclusively (but not only) in apple production. The cost of orchard establishment is a fortune. Without subsidies it is impossible to have an intensive orchard with all the requirements. It is claimed by Ferenc Apáti, the president of FruitVeB, that while 3-4 years ago the cost of orchard establishment was around 10-12 million HUF per hectare, in 2023 an intensive plantation, equipped with all the necessary tools could cost around 25 million HUF. Even when the orchard is developed enough, the price of the fresh apple is not promising. Recently, Hungarian farmers can sell apple for 130-160 HUF/kg for suppliers. That is why the production is barely feasible. Due to the lack of improvement the processed apple that is produced is relatively high in volume compare to fresh apple. Apple for processing is sold for 40-50 HUF/kg.

As it was mentioned previously, the yield is very fluctuating. By observing data that is published by KSH (Central Statistical Office in Hungarian) the yield in 2022 was roughly 350 000 tons in the country. However, in 2021 it was 514 000 tons that was 164 000 tons more. But in 2020 it was below 400 000 again. The peak year in the last decade was 2014 with 779 000 tons. Despite, the main influencing factor of the yield is the weather, it not affects on the same way in every region of Hungary, even though it is a small country. For Instance, in 2022 the yield in the Great plain (that is the main apple growing area) was dramatically low, in the Western part of the country it was a decent yield compare to the previous years. The yield can either increase or decrease season after season, but overall, there is a clear decline from the second half of the XX. century. Nowadays, approximately only the 1/3 of the yield is produced like 40-50 years ago. This is true for every other fruit as well (if not more serious the decline is).

KSH got the fruit orchards into statistics. From the report from 2017 it was turned out that the apple is produced on 34% of the area of Hungarian fruit orchards. Totally it was 25 044 hectares of apple in 2017. From this 3 347 was more than 24 years old, and 1 912 hectare was at least 20-24 years old, so it means that around 21% of the Hungarian apple orchards were at least 20 years old. The hectares were summed and classified by condition as well. 4 477 hectare is considered as it is in excellent shape, 11 006 hectares as good, 7 118 hectares as average, 1642 hectare as weak and 800 hectare is classified as very weak. Unfortunately, in 2017 71% of the plantations were not have support system. All in all, 21% of the apple orchards are irrigated. In 2023 around

2000-2500 hectares of apple orchard which have irrigation system, support system and hail protection net. In his interview it is assumed by Ferenc Apáti that a modern orchard can produce 2-3 times more than an extensive, old-fashioned one.

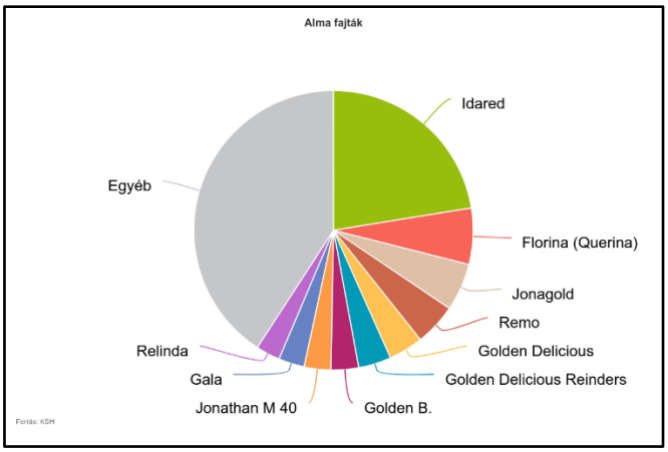


**Figure 3.1:** The distribution of apple cultivars by producing hectares in Hungary on a pie-chart

source: KSH

As it can be seen on figure 3.1, the most produced cultivar in Hungary is 'Idared'. Based on KSH's sources, in 2017 the cultivar was produced on 5 643 hectares. The second most produced cultivar is Florina with 1 619 hectares, and the third most planted one is 'Jonagold' with 1 3667 hectares. Overall, 153 cultivars were declared by farmers. It is also mentioned in the report that the Pinova group (group of cultivars) has given the 27% of the produced apple area. These cultivars have gained the popularity among the farmers due to the fact that these ones are resistant against some key diseases that is very important point from the farmers' aspect.

### CONSUMPTION TRENDS IN HUNGARY

"One apple a day, keeps the doctor away"- This is what everyone has heard before but in reality- Hungarians do not eat one apple per day. Based on KSH's data, in 2019 a Hungarian ate 12,5 kg apple within a year. That means that by calculating with 200 g as an apple, totally it is 62,5 apples per year. It only covers 2 months basically. Three years later, 2022 it was said that this number is at 15-16 kg per person. Mr. Zsolt Feldman, the State Secretary for Agriculture and Rural Development of the Ministry of Agriculture has claimed that apple is the most bought grocery product in Hungary. It was also said by him, that Hungarians are rooting for fresh top quality and local apple, that could be consumed not only as fresh but as juice, puree or dried form. It was Ferenc Apáti who mentioned in an article that normally the Hungarian fresh apple consumption is between 120-140 000 tons. In a good year on paper Hungary could cover its market with own apple, but the truth shows that in years like 2022 or 2011, when the yield is drastically low, the demand could be covered only with import.

In theory, the campaign of promoting local apple for Hungarian costumers would be nice but in reality, there are some circumstances which makes it harder. Enormous amount of Polish apple arrives to the market every year. Especially, since the Ukraine-Russia war, the possibilities of Russian market are locked, so it spreads more Polish apple into Hungary. On the other hand, the previously discussed fluctuating yield, makes the prices unstable as well. Not to mention the increase of cost of production that is happening since the Pandemic due to different reasons. Obviously, this ends up in the final price of the apple. In any case, apple is still considered as a cheap fruit crop that is available on the market all year-round. In one hand affordable apple is a good thing especially from costumers' view, but on the other hand it is common that the price of the apple in the supermarket and grocery store is way lower than it should be. This means that the seen prices are not that different compared to previous years, before serious inflations and production cost increases. The actual price is not affected by higher costs of the farmer.

# 4. MATERIALS AND METHODS

## 4.1 MATERIALS

### 4.1.1 MATERIALS FOR THE RESEARCH

For the apple storability experiment the following materials and tools were used.

Apple: The apple that was used were collected from the home orchard. The following cultivars were used: 'Granny Smith', 'Idared', 'Jonagold', 'Karneol' and 'Rodonit'. The orchard is in North-West Hungary, in Fertod. It is totally 7,5 hectares big. The rows are 100 meters long and N-S lined. The area is completely flat, there isn't any altitude change within the orchard. From the west side it is bordered by a forest belt. On the north and east edge there is an agricultural field that is having different kind of arable crops year after year. The southern side is an unused bushy area and next to it is a part of the buildings of the agricultural enterprise. The orchard has four plantations based on age. The oldest one was planted in 1996. From this 'Granny Smith' was collected. There is an orchard from 2014 that was the source for 'Idared' and 'Jonagold'. 'Karneol' and 'Rodonit' were harvested from the orchard that was planted in 2017. The fourth orchard was established in 2012. Every cultivar was collected three times with 10-10 days differences. They were picked on 21.09.; 01.10; 10.10. Overall, it means that fifteen trays of apple were collected (3 occasions x 5 cultivars). These plastic trays were not get filled with apple fully, only approximately 5-5 kg each. The trays were placed next to and above each other into three columns, split by the harvesting time. These trays were not kept isolated from the other apples that were stored there.

Storehouse: The place where the apple was kept is a freshly renovated storehouse. The size of this room is 16mx8mx3,8m= 486,4 $m^3$. The temperature was set to 4 °C constantly and the range of the temperature was around 5,5 and 3 °C because it is important to mention that the storehouse was used throughout the research so by going in and out the temperature could have been disrupted. It was packed fully with apple and only one pallet was for the research.

The penetrometer for the flesh firmness and the sugar meter for the Degrees Brix measuring were borrowed from the Department of Pomology of the university. The spring grip is a manual meter that works by forcing pressure with it, in this case to the surface of the apple. The sugar meter runs with a battery. Small amount of pulp should be poured to the hole of the tool and then by pressing the button the sugar degree will be measured.

### 4.1.2 MATERIALS FOR THE SURVEY

The survey for the apple consumption trends were created on Google Drive by using the Google Form function. The whole survey is bilingual, as to get answers not only from Hungarians, but from foreigners too. It is assumed that by this way the result will be more complex and a wider overview is got. The survey contains 13 questions from which 3 questions are for specify the person completing the form by asking gender, age and nationality. Apart from these, there are no other data about the people. The rest 10 questions are about the apple consumption trends. Totally 83 individuals filled out the questionnaire. From this 65 (78,3%) were Hungarian and the rest (21,7%) from all around the world.

## 4.2 METHODS

### 4.2.1 METHODS OF THE RESEARCH

The measurements were happened three times. The first date was 20.12 then the second one on 25.01. and the last one on 01.03. Each time 3 sample were taken from each tray and being measured as soon as possible, and trying not to keep the apples on room temperature for a long time. The taste test was focussing on the flavour and the consistency of the apple. This test was an organoleptic test. The tastings each time were performed by the same three people from the household. The gained data were noted into an excel spreadsheet directly.

### 4.2.2 METHODS OF THE SURVEY

The survey was published on 18. October 2022 and it was available until 03. December 2022. The document was made as a Google form and it was shared on social media platforms. 83 responses have arrived. 80% of the answers arrived from Hungary and the rest all around from the World. They arrived from France, Colombia,

Italy, United States, Greece, Spain, Netherlands, Albania, Indonesia and Germany. The form's questions were added in two languages, in Hungarian and in English.

69% of the answers were women and the rest 31% were men. As the age, more than half of the answers, 51% came from people who are 20-29 years old. Moreover, 19,3% were people within 50-59 years. In the form, apart from the simple questions of age, gender, and nationality some of the questions were test like questions, some offered the possibility to give multiple answers. While some asked to give rankings, normally from 1 to 5 interval. Here are listed every question from the survey, related to the apple consumption trend topics.

- How often do you consume apple in average per year?
- How often do you consume apple in average during the apple season?
- How strongly do you take into consideration the following factors during purchasing? Rate from 1 (not at all) to 5 (totally)
- Do you have any idea what does resistancy means in the case of apple cultivars?
- The resistance apple cultivars (and other plant varieties) were bred to prevent the yield from diseases that would result yield loss. Due to this, new cultivars appeared on the market by which farmers would like to replace the old cultivars. Usually, every new variety is to swap an old cultivar by having nearly the same old, well-known taste. Would you prefer to buy resistance apple, if you would be aware of which type of apple is that?
- From the following list, which apple cultivar do you know?
- From the following list, which apple cultivars do you prefer?
- On a scale what are your preferences related to the taste of the apple?
- How far would you go to buy apple? (Let's say you have access to a car)
- What facilities would you take into use to buy apple from the following list, that could be offered by a farmer?

# 5. RESULTS

In the following paragraphs the results are listed. In the case of statistical analyses, SPSS was used.

## 5.1. RESULTS OF FLESH FIRMNESS, SUGAR CONTENT

The results are listed cultivar by cultivar.

### 5.1.1. RESULTS OF FLESH FIRMNESS OF 'GRANNY SMITH'

The Univariate Analysis of Variance test was used to see whether any significant difference between the means of flesh firmness of 'Granny Smith' apple is there. The dependent factor was the flesh firmness and the fixed factors were the measuring date and the harvesting date. The level of significance was adjusted to 95%. The test, which involved three measurement occasion throughout storing, has showed that there is significant difference between the means of flesh firmness of the 'Granny Smith' apples that were picked different times. By using a post-hoc test, a multiple comparison was created. it can be stated that the significant difference is between the first and the third harvest, and between the second and third picking. In the case of the first and third harvest, the p-value (Sig.) was >0,001 that is less than the adjusted 0,5 significant level, and the difference was -,8278 as it can be seen in appendix 1. In the case of the second and third harvest the mean difference is -,5000. This difference is shrinking during the storage as it is seen on figure 5.1.1

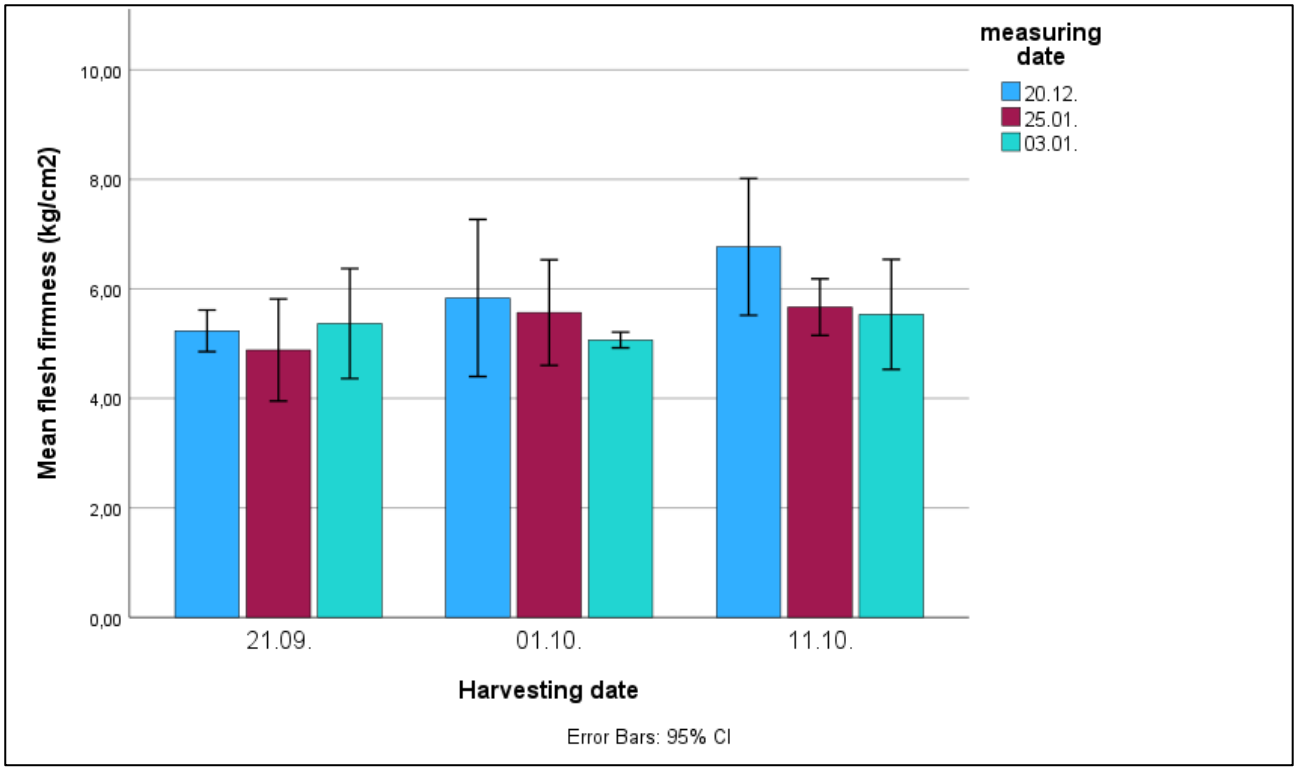


**Figure 5.1.1:** Clustered Bar chart of flesh firmness of ''Granny Smith'' by harvesting date where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

By the chart it can be noted the flesh of the earlier picked apples are harder especially in the case of the first and second and the third harvest. In the case of the first harvest the chart does not show a continuous decline. At the first measurement the mean of flesh firmness was nearly the same if not less than at the third measurement, although the minimum got lower. The samples that were taken at 01.10. are showing the most "expected" trend of flesh firmness decrease over storage time. But at the second harvest the first measurement that was at 20.12. are resulted quite wide standard deviation. The mean of the third harvest is also presenting a decline over time. If for a costumer the strong flesh firmness is important, it is advised to buy apple earlier. Although, it is important to mention that ''Granny Smith'' has relatively harder flesh compare to the other cultivars that were measured and will be presented later on.

### 5.1.2. RESULTS OF SUGAR CONTENT OF 'GRANNY SMITH'

The Univariate Analysis of Variance test was used to see whether any significant difference between the means of sugar content of 'Granny Smith' apple is there. The dependent factor was the sugar and the fixed factors were the measuring date and the harvesting date. The level of significance was adjusted to 95%. The test, which involved three measurement occasion throughout storing, has showed that there is significant difference between the means of Brix value of the 'Granny Smith' apples that were picked different times. By using a post-hoc test, a multiple comparison was created. it can be mentioned that the significant difference was between the first and the second harvest, and between the second and third picking. At the first and second harvest the mean difference was 1,2889 and the p-value (Sig.) was 0,002 that is less than 0,05 level of significance. In the case of the second and third harvest the difference was between the means was absolute value of 1,0667 with a 0,006 significant that is less than 0,05. These data that were just mentioned could be seen in appendix 1.

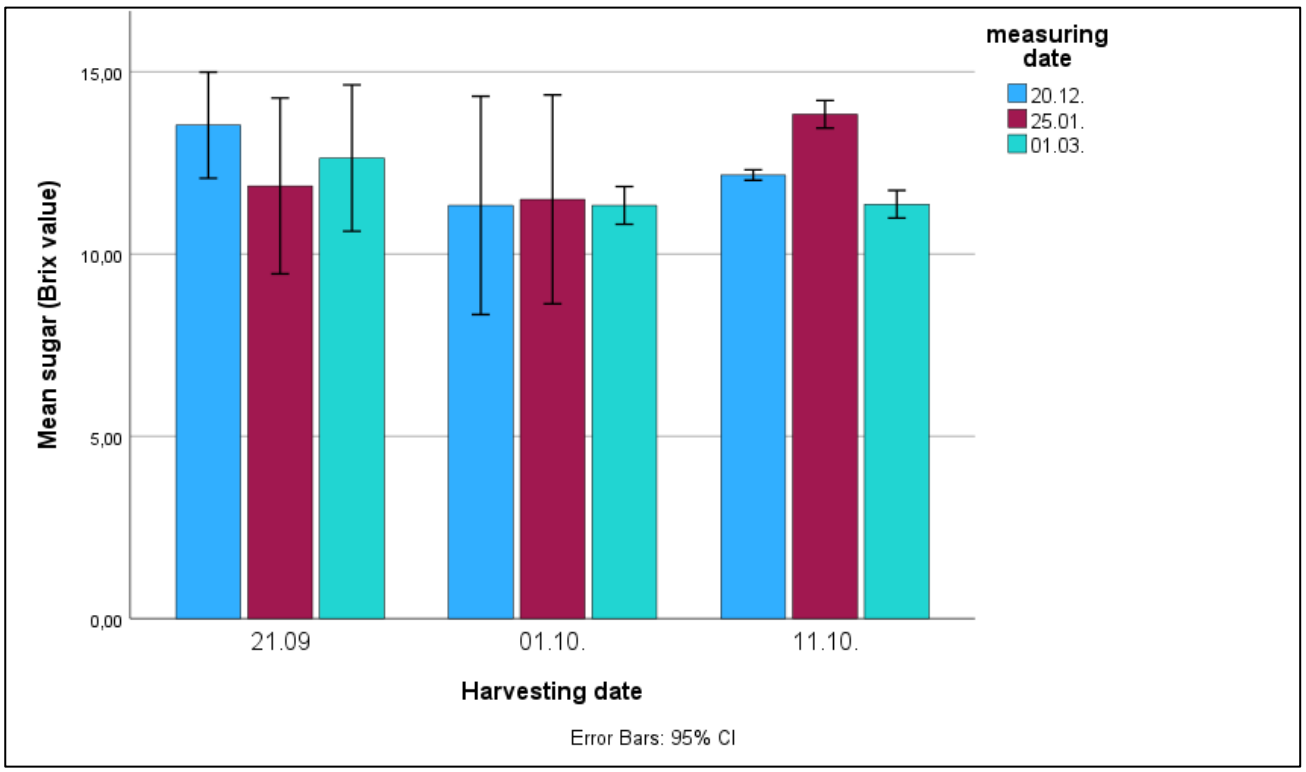


**Figure 5.1.2:** Clustered Range Bar chart of Brix value of ''Granny Smith'' by harvesting date where the bars are representing the means of the Brix value and the whisker's lower end the minimum and the upper end the maximum.

On the figure 5.1.2. the measured Brix values of ''Granny Smith'' are visualized. Each, column involves three data. In the case of the harvest 21.09. the values were higher at the first measurement, then declined. But at the third measurement, it was higher again. The standard deviations (represented by whiskers) are considerably big in the case of all the three measures of the first harvest and are following the curve of the means. The second harvest's numbers are showing a constant state as none of the three measurements' results differ significantly. However, in the case of this harvest the first and second standard deviation are generally wide especially compare to the last, the third measurement's whisker. The third harvest's result are seemed to be the most accurate, as the standard deviation is low in the case of all the three measurements. In the case of the last harvest, the second measurement has resulted a huge increase, but the third one brought results that are slightly lower than the first occasion pf sampling had. All in all, every received Brix values was between 10 and 15.

### 5.2.1 RESULTS OF FLESH FIRMNESS, SUGAR CONTENT OF 'JONAGOLD'

The Univariate Analysis of Variance test was used to see whether is there any significant difference between the means of flesh firmness of 'Jonagold' apple. The dependent factor was the flesh firmness and the fixed

factors were the measuring date and the harvesting date. The level of confidence level was 95%. The experiment which concluded three measurement occasion throughout the time of storing, has showed that there is significant difference between the means of flesh firmness of the ''Jonagold' apples that were picked different times. By using a post-hoc test, a multiple comparison was created. It turned out that there is no significant difference between the different harvesting dates and none of the significances were below the level of significance.

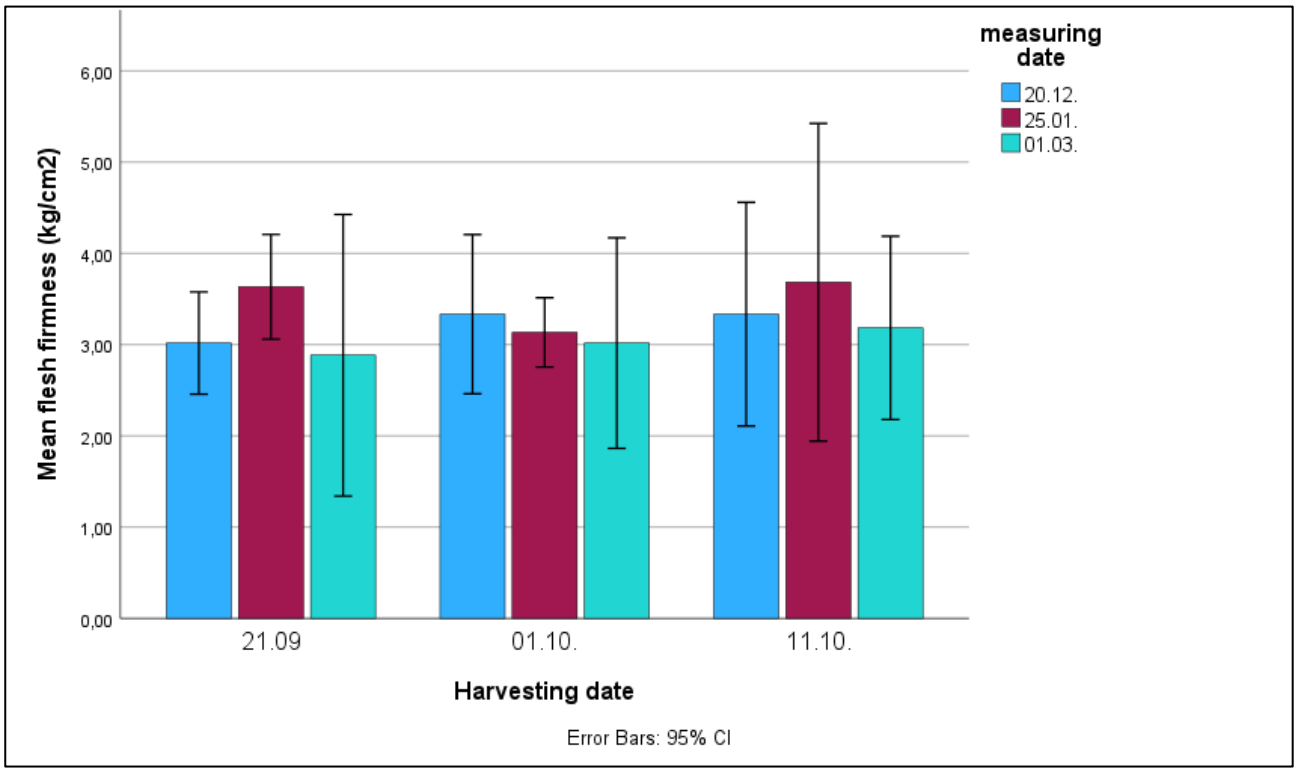


**Figure 5.2.1:** Clustered Range Bar chart of flesh firmness of 'Jonagold' by harvesting date where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

On figure 5.2.1. it can be seen that the biggest difference between the means is between the first and third harvest second measurement and the first harvest third measurement. By analysing the pickings individually, the following statements can be claimed: The first harvest is showing an increase then a decrease over time. Overall, the third sampling has showed lower flesh firmness than the first one. But in the case of the third time measure, the standard deviation is quite wide compared to the first two measure. The second harvest is going through an overall decline over the storage. The means are decreasing in order, although the standard deviation is a bit bigger in the case of the first and second measuring occasion. The third harvest has a line similar to the first harvest: increase, decrease. The standard deviation is pretty wide in the case of the blue and the red column. For the third harvest the difference between the means of the first and the last measuring is negative. By observing the different measuring days (represented by different colours) it can be mentioned that overall, the later the apple is picked the more likely that the flesh firmness will be higher. The only data that is outstanding is the first harvest second examination, where the data was higher then the following third measurement. Also, at the first measurement the second and third harvest are nearly have same means, but apart from these mentioned exceptions, the following results are always higher than the previous ones.

### 5.2.2. Results of sugar content of ''Jonagold'

The Univariate Analysis of Variance test was used to see whether is there any significant difference between the means of sugar content of 'Jonagold' apple. The dependent factor was the sugar (Brix value) and the fixed factors were the measuring date and the harvesting date. The level of confidence was adjusted to 95%. The test, that was containing three measurement occasions throughout storing, has showed that there is no

significant difference between the means of Brix value of the ‘‘Jonagold’ apples that were picked different times. As the lack of significant difference, no post-hoc test was needed. So, it can be said that there might be changing in the soluble concentration, the difference is not statistically different.

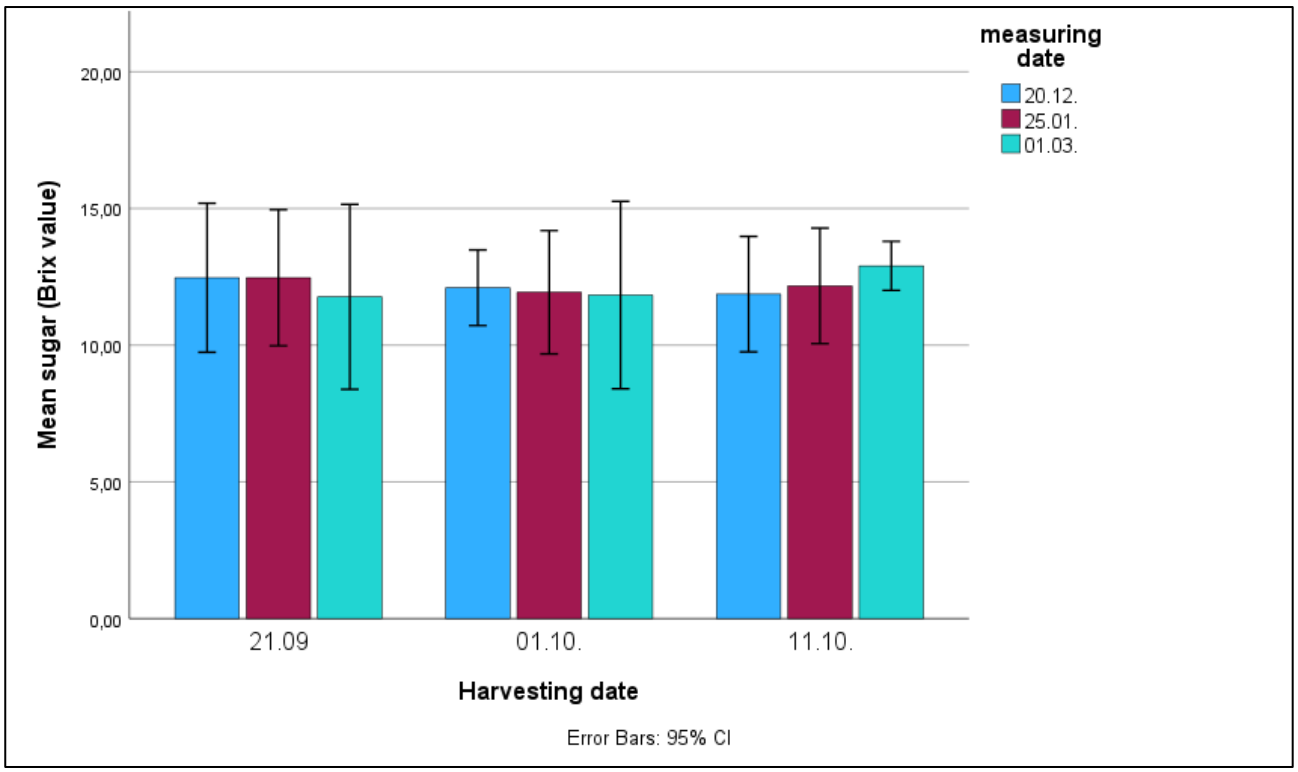


**Figure: 5.2.2.:** Clustered Range Bar chart of Brix value of ‘Jonagold’ by harvesting date where the bars are representing the means of the Brix value and the whisker’s lower end the minimum and the upper end the maximum.

On Figure 5.2.2. the means of Brix value of ‘Jonagold’ are presented. It can be seen well, that the columns are reaching more or less the same height on the vertical (Y) axis. In the case of the first harvest there is a slight decline among the means over storage. The standard deviations are relatively wide in the for all the three bars. The second harvest’s means are also presenting a narrow decreasing one after each other. Interestingly, the minimums are showing decline as well, but the maximum value of all the three samplings occasion came higher and higher. For the last harvest it can be told that the means are growing over storage unlike the first and second harvest. So, as the minimum values of the third harvest are increasing as well, but the maximum values are not. The standard deviation of the last harvest’s last measurement is the tightest. As the Brix value is referring for the concentration of sucrose (1g of sucrose in 100ml of solution), it can be stated that the last harvest came the sweetest for the last time of measuring. This could mean that those apple from the last harvest lost the most moisture during storage, and thanked to the earlier harvest the first and second harvest was prevented from severe water loss during storage. Whereas, it was mentioned previously, none of the results were significantly different compare to each other, so it would be really bold to say that in the case of ‘Jonagold’ the later harvest results more serious moisture content decrease over time. Another reason for high Brix could be for the more sucrose that is because of the starch decomposition, but for that especially, an initial measurement right after harvest, could have been crucial.

### 5.3.1 Results of flesh firmness of ‘Idared’

The Univariate Analysis of Variance test was used to see whether is there any significant difference between the means of flesh firmness of ‘Idared’ apple. The dependent factor was the flesh firmness and the fixed factors were the measuring date and the harvesting date. The level of confidence was set to 95%. Throughout the storing period there were three times of sampling for the flesh firmness. The testing, has showed that there is significant difference between the means of flesh firmness of the ‘Idared’ apples that were picked different times. By applying a Post-Hoc test, a multiple comparison was created. it can be stated that the significant difference

is between the first and the second harvest. At this comparison, the p-value (Sig.) was >0,001 that is less than the adjusted 0,5 significant level, and the difference was absolute value 0,5889 as it can be seen in appendix 2.

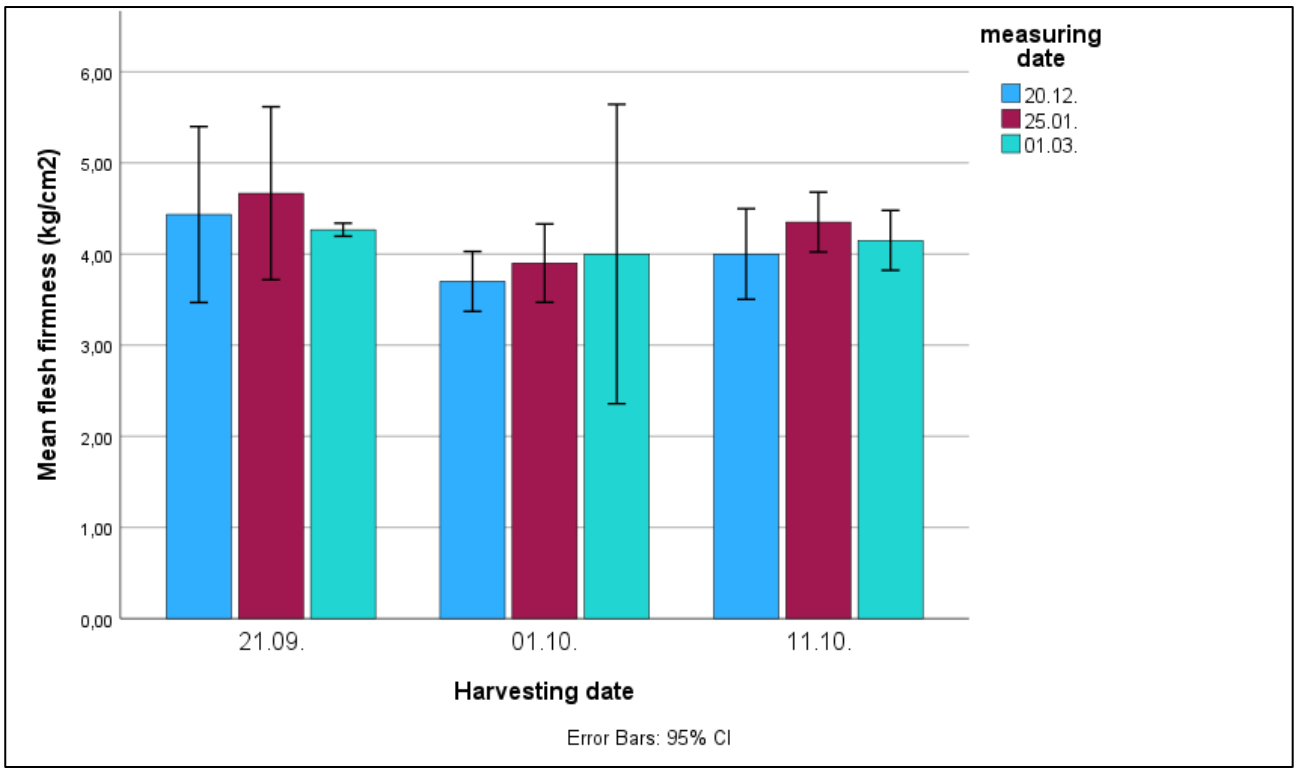


**Figure 5.3.1:** Clustered Range Bar chart of flesh firmness of 'Idared' by harvesting date where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

On figure 5.3.1 the different flesh firmness data are presented. In the case of the first harvest, the mean increased for the second testing but decreased for the third one. It got less than for the first measuring. The standard deviations of the first harvest are either pretty loose as it can be seen for the blue and red bar, while for the greenish bar the minimum and the maximum are undoubtably closer to each other. The second harvest that was done on the first day of October, is showing a continuous increase between the means over the storage, but none of the flesh firmness means are resulted a higher bar than any other harvest's any measurement. The means of the second harvest is the lowest from all. The standard deviation of the second harvest's third measurement is enormous. The third harvest's bars are following the same curving as the first harvest results. This increase and decrease are seen in the minimum, maximum as well. However, the last measuring gave higher flesh firmness data than the first one. By viewing the whole chart, it is interesting that the greenish bars are almost the same high, so by the last measuring difference between the harvest dates a seemed to disappear. However, if we group the three-three measuring occasion by harvest dates, it can be mentioned that the first harvest carried the greater flesh firmness numbers, and as it is seen on the figure 5.3.1. the first harvest's bars are overall higher than the others.

### 5.3.2 Results of sugar content of 'Idared'

The Univariate Analysis of Variance test was applied to see whether is there any significant difference between the means of sugar content of 'Idared' apple. The dependent factor was the sugar and the fixed factors were the measuring date and the harvesting date. The confidence level was adjusted to 95%. The test, which involved three measurement occasion throughout storing, has showed that there is significant difference between the means of Brix value of the 'Idared' apples that were picked different times. By using a post-hoc test, a multiple comparison was created. it can be stated that the significant difference was between the first and the third harvest. At the first and third harvest the mean difference was absolute value 0,7333 and the p-value (Sig.) was

0,044 that is less than 0,05 level of significance. These data that were just discussed could be seen in appendix 2.

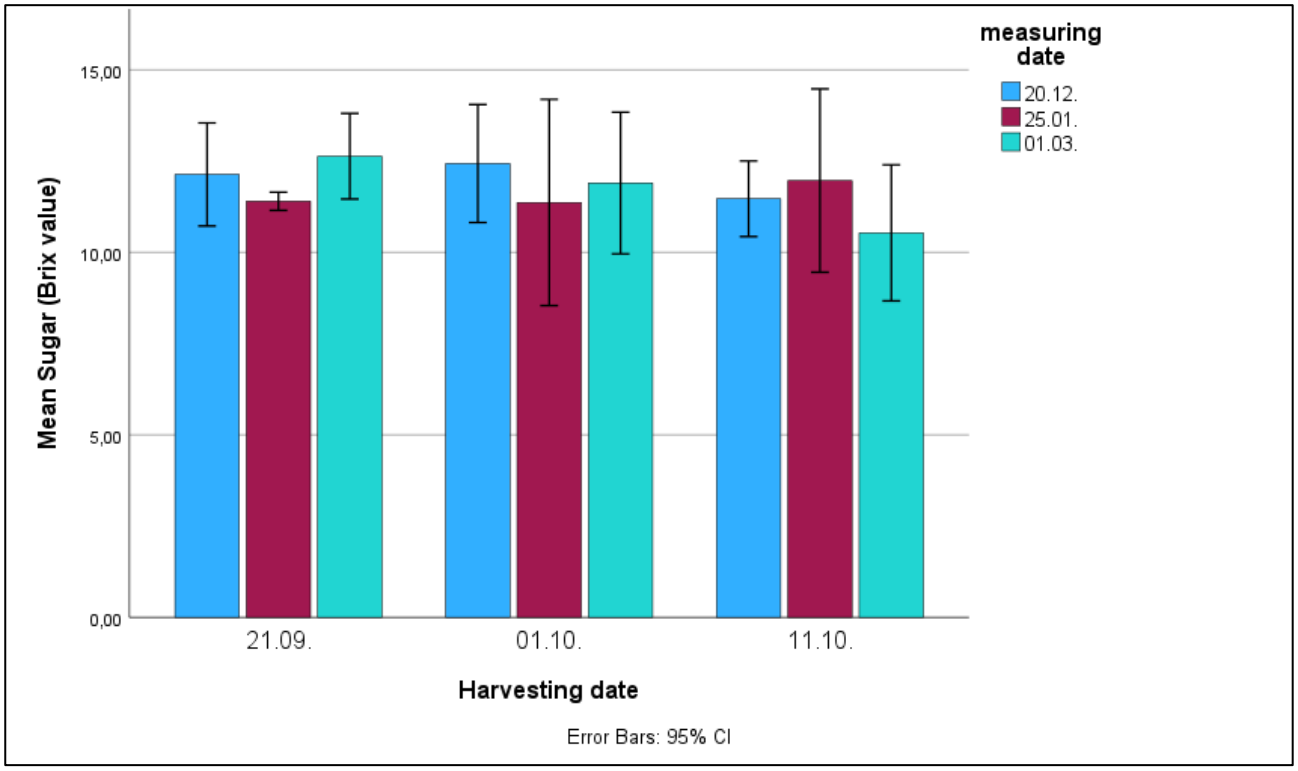


**Figure: 5.3.2.:** Clustered Range Bar chart of Brix value of 'Idared' by harvesting date where the bars are representing the means of the Brix value and the whisker's lower end the minimum and the upper end the maximum.

The chart on figure 5.3.2. are representing the change of sugar concentration (in Brix values) of 'Idared' during the storage. The first harvest's results have a 'V' shaped curve so the second measuring has lower mean than the first one, but lower as well compared to the third one. By the 1 March (when the last occasion of sampling happened) the Brix values were higher than before. The standard deviations are relatively narrow, especially the red column where the minimum and the maximum end of the whisker are close to each other. The second harvest has resulted a same shape within the bars, like the just discussed first harvest. However, unlike at the 21.09. harvest, at the 01.10. the last sugar content examination reached lower numbers than the first measuring. The standard deviations are absolutely wide. In the case of the last harvest, the curving of the bars on the chart are an opposite "V" shape. The first measuring of the last harvest has nearly the same mean as the second measurement of the previous two harvest. The red bar of the 11.10. harvest is tended to be around the same height as the greenish bar at the previous apple collection. The last measurement of the last harvest ended up with the lowest Brix value at all, so the significant difference is taken into account, that was stated before, it is likely that the significant difference is between the last harvest's last measurement and the first harvest's first and second measurement and the first measurement of the second apple harvest, as among these are the biggest difference between the means.

### 5.4.1 Results of flesh firmness of 'Karneol'

The Univariate Analysis of Variance test was used to see if there is any significant difference between the means of flesh firmness of 'Idared' apple. The dependent factor was the flesh firmness and the fixed factors were the measuring date and the harvesting date. As previously, the level of confidence was set to 95%. During the storing period there were three times of sampling for the flesh firmness. The statistical analysis showed that there is no significant difference between the means of flesh firmness of the 'Karneol' apples that were picked different times. As there were no significant difference, it was not necessary to do a multiple comparison post-hoc test in SPSS. The received data are all within the interval of 3 and 4 kg/cm$^2$.

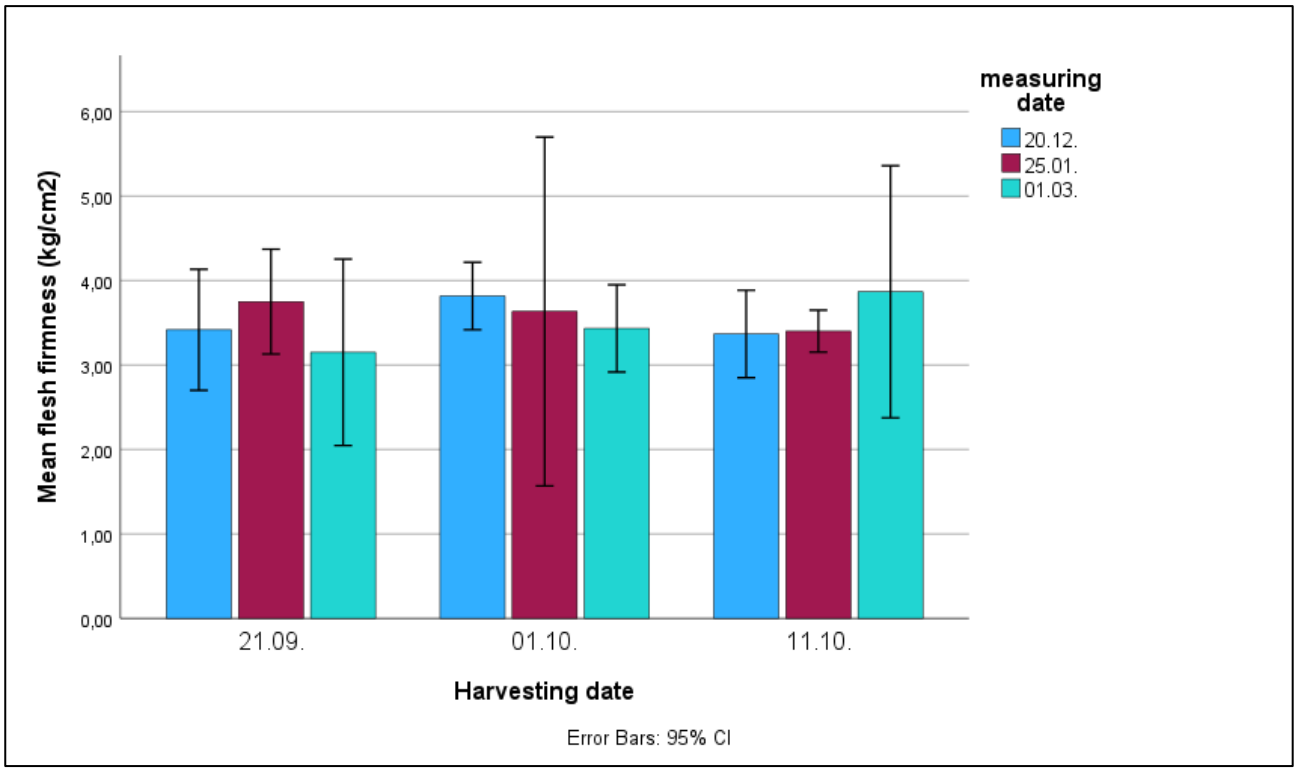


**Figure 5.4.1:** Clustered Range Bar chart of flesh firmness of 'Idared' by harvesting date where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

The flesh firmness change of 'Karneol' is visualized by a clustered bar chart on figure 5.4.1. The first harvest had an increase then a decline in the means of the firmness. Not only the mean but the minimums and maximums are followed the same change over time. It's last time of measure came the lowest bar on the chart, that is barely overpass the 3,0 kg/cm$^2$. What is more at that particular greenish bar, the standard deviation is unquestionably wide. The second harvest on the chart is indicating a continuous even decline during observed interval of the storage. The first measurement had the highest mean, then the second one and lastly the third measurement. What is really outstanding at the second harvest's bars is the standard deviation of its second harvest. The minimum value is between 1,0 and 2,0 kg/cm$^2$ while the maximum value is almost reaching the 6,0 kg/cm$^2$. From the view of the second harvest, it can be assumed that there is a quality loss over storage as the flesh firmness is getting less and less. This statement would not fit to the last harvest where the first and the second measurement had approximately the same mean value, the last measurement finished with a high one, actually the highest mean all in all on this chart. What is more the standard deviation of that measuring came a quite big one as well. Furthermore, by the last sampling (that are the greenish bars on the chart), it is seen that the earlier the harvest was, the flesh firmness quality got lower, while previously this assumption would have been completely the opposite, as the red bars are declining as the harvest was latened.

### 5.4.2 Results of sugar content of 'Karneol'

The Univariate Analysis of Variance test was chosen to apply so as to see whether is there any significant difference between the means of sugar content of 'Karneol' apple. The dependent factor was the Brix value and the fixed factors were the measuring date and the harvesting date. The confidential level was set to 95%. The sampling that involved three measurement occasion throughout an interval of storing, has indicated that there is no significant difference between the means of Brix value of the 'Karneol' apples that were picked at different times. However, it turned out that there was significant difference at the first measurement, even though this significancy disappeared later on. A multiple comparison was made by post-hoc test. At the first measurement that was in December the means of the first and second harvest were significantly different like the last harvest. The mean difference was absolute value 2,667 and 1,500 and the p-value (Sig.) was 0,006 and 0,031 as it can be seen in Appendix 3. What is more the difference was significant at the last measurement as well, between

the first and second harvest. At this time the mean difference was absolute value 1,8667 and the significance was 0,025 (appendix 3.).

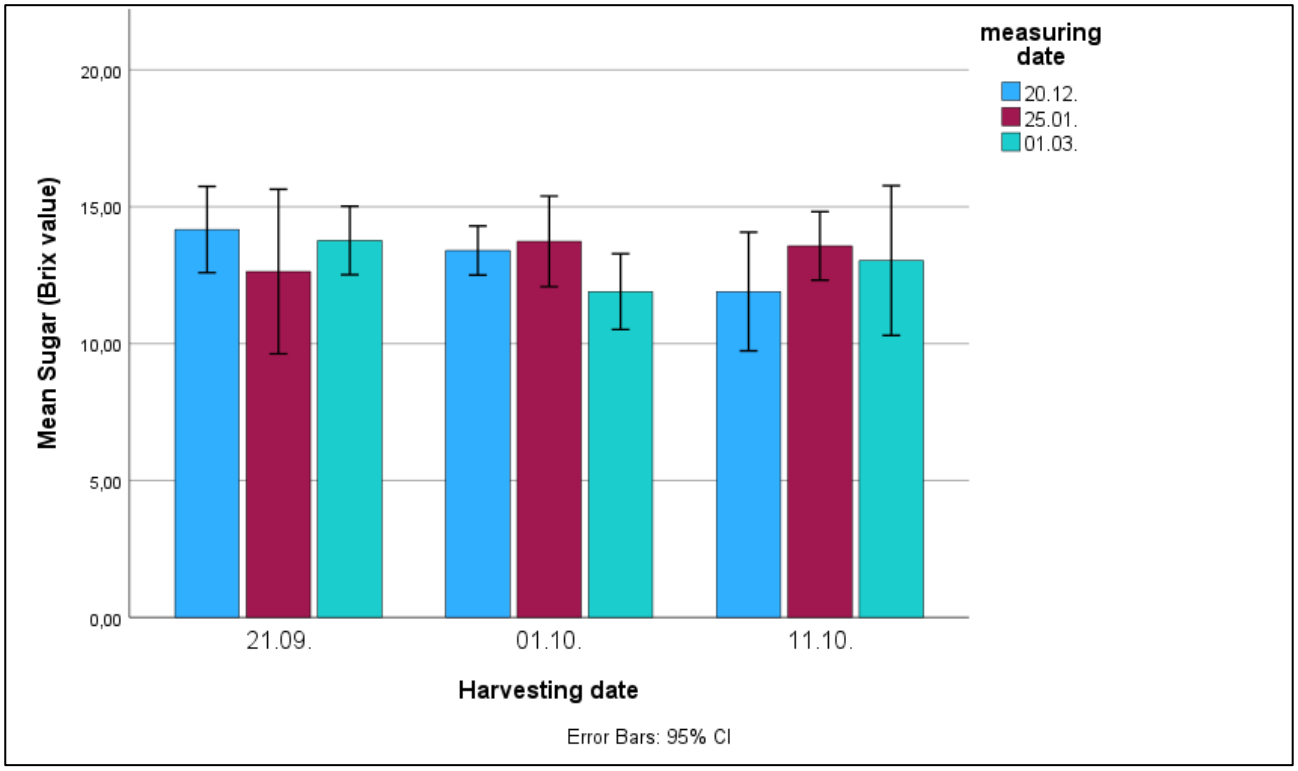


**Figure: 5.4.2.:** Clustered Range Bar chart of Brix value of 'Karneol'' by harvesting date where the bars are representing the means of the Brix value and the whisker's lower end the minimum and the upper end the maximum

The figure 5.4.2. are serving for presenting the Brix value change in 'Karneol' over the period of storage. The first harvest has a slight "V" shape curve by its three bars. The first sampling resulted the greatest sugar concentration not only at the first harvest but all in all at the entire sugar measuring of 'Karneol'' apple. The maximum values are showing a slight decline, and at the second measurement the standard deviation is more than 5 unit. In the case of the second harvest the first two result is not that different compared to each other, but the last one is. This greenish bar is carrying the lowest mean of Brix value of the 'Karneol' sugar concentration sampling. The standard deviations are not outstandingly big, but could not be assumed as small. The last harvest's blue bar (so the first measuring) is around the same high as the previously discussed second harvest's last measurement. Whereas, at the second measurement the last harvest's had higher sugar concentration in the examined apple samples. The last measurement is showing a minimal decline compared to the one before. As the significant difference occurrence was detailed in the paragraph above the figure, it is clear that the mean of sugar concentration between the different harvests were the closest to each other at the end of January when the second measuring happened.

### 5.5.1 Results of flesh firmness of 'Rodonit'

The Univariate Analysis of Variance test was used to see whether is there any significant difference between the means of flesh firmness of 'Rodonit' apple. The dependent factor was the flesh firmness and the fixed factors were the measuring date and the harvesting date. The confidential level was adjusted to 95%. The test, which involved three measurement occasion throughout storing, has showed that there is no any significant difference between the means of flesh firmness of the 'Rodonit' apples that were picked different times. As there were no clear significant differences, it was also statistically analysed if at one occasion of measurement is there any significant differences among the different harvests, but the result was that there is no significant difference among the different harvests during the observed period of the storage.

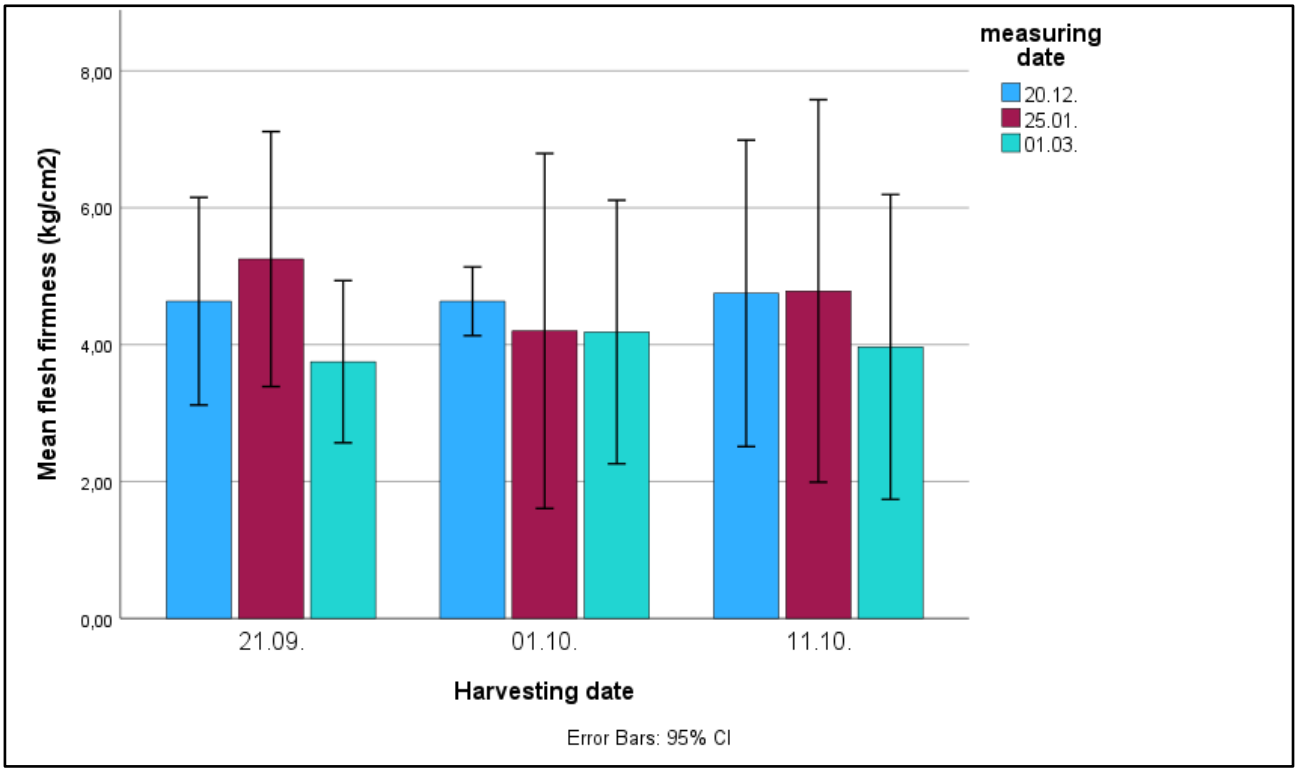


**Figure 5.5.1:** Clustered Range Bar chart of flesh firmness of 'Rodonit' by harvesting date where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

Figure 5.5.1 is showing the change of flesh firmness in 'Rodonit' during storage. It is seen that the first harvest produced the highest and the lowest mean values during the examined period. By the second measuring date, it had developed a notable increase, but for the last one, on 1 March, it resulted the lowest mean among all the other harvests. The highest value that was measured was around 6 kg/cm$^2$ and it was measured at the second occasion as it can be seen as the maximum value on the red bar at the first harvest. The second harvest was not showing any increase in its flesh quality as after the first measure the values got lower for the 25. January and it was not really different by the last measure as it is visible on the figure that the red and the greenish bar of the second harvest are having more or less the same height, despite the fact that these two bars are indicated with relatively wide standard deviations. The last harvest is showing some similarities to the previous harvest bat at the case of this one, the first two measurements came around at the same value, while the last measurement had a result that is an although not significant, but on the chart well visible decline. All in all, it can be discussed that in the case of every harvest, by the end of the target period of storage, the flesh firmness had loosened from its quality and the flesh of the 'Rodonit' apples got absolutely softer.

### 5.5.2 Results of sugar content of 'Rodonit'

The Univariate Analysis of Variance test was chosen to apply so as to see whether is there any significant difference between the means of sugar content of 'Rodonit' apple. The dependent factor was the Brix value and the fixed factors were the measuring date and the harvesting date. The confidential level was set to 95%. The sampling that involved three measurement occasion throughout an interval of storing, has indicated that there is no significant difference between the means of Brix value of the 'Rodonit' apples that were picked at different times. By running a statistical analysis, it was seen that there is no significant difference among the different harvests, and the different harvest date doesn't really make difference in the sugar concentration within the apples. However, there was significant difference between the second and the last measurement of the third harvest. The mean difference was absolute value 4,0667 and the p-value (Sig.) was 0,049 that is less than the set level of significance (0,05). For this a Multiple comparison was made by a post-hoc test, that is seen in Appendix 4.

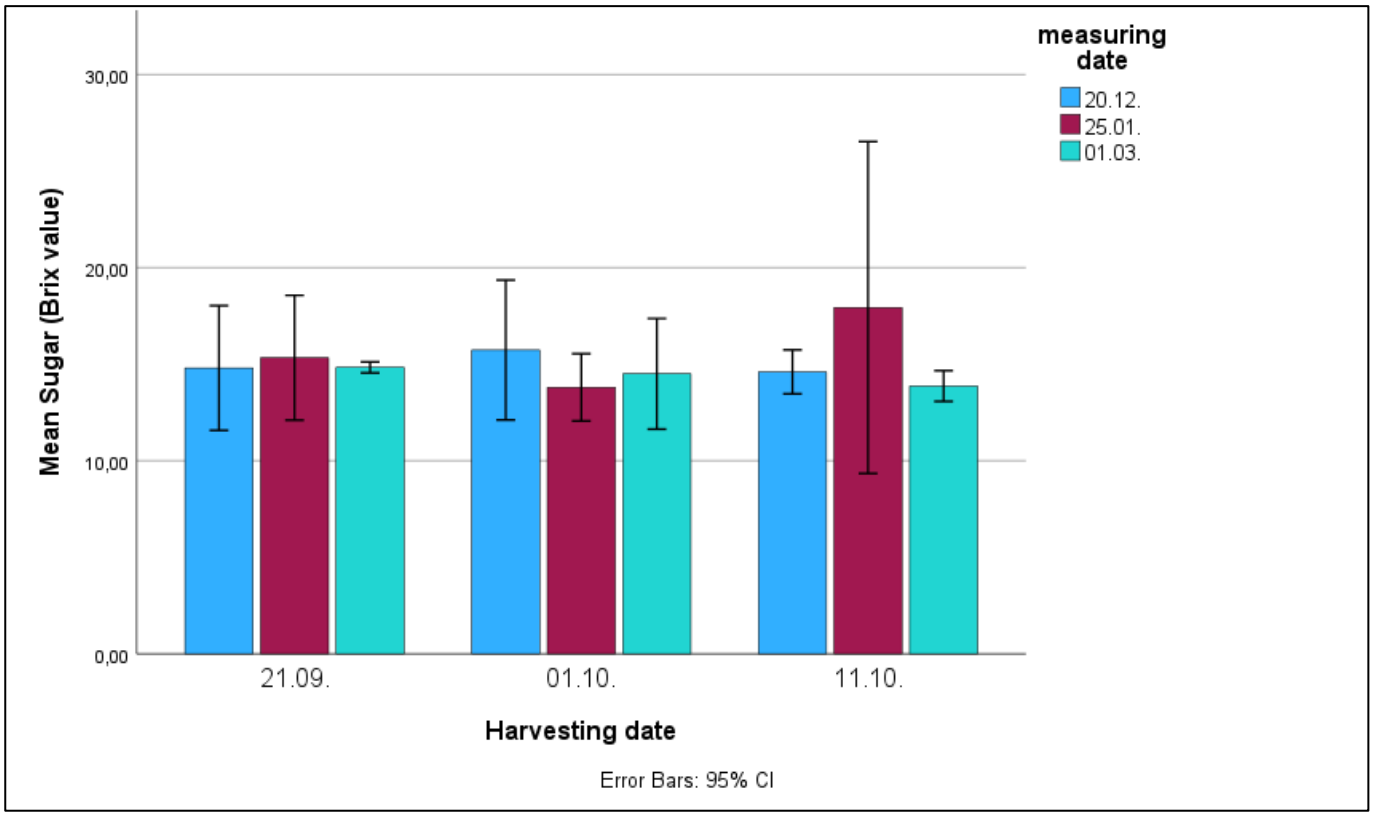


**Figure: 5.5.2.:** Clustered Range Bar chart of Brix value of 'Rodonit' by harvesting date where the bars are representing the means of the Brix value and the whisker's lower end the minimum and the upper end the maximum

On figure 5.5.2 the change that has happened in the Brix value of 'Rodonit' apple are presented. It is seen that the first harvest's values are all around at the same level throughout the observed period of storing. The chosen apple samples from the second harvest had a decline by the second date of measure, but it got closer again to the 15% Brix by the last measurement. The standard deviations are relatively narrow. The last harvest had a massive increasement in the sugar concentration by 25 January when the second sampling happened. Whereas, it dropped back by the last measuring. What is more, that last value of the third harvest is the lowest value at all. Unfortunately, it is a bit harsh to take any assumption regarding the change of soluble concentration in 'Rodonit' as none of the bars are following a visible order.

## 5.6 COMPARISON OF FLESH FIRMNESS OF THE FIVE APPLE CULTIVARS

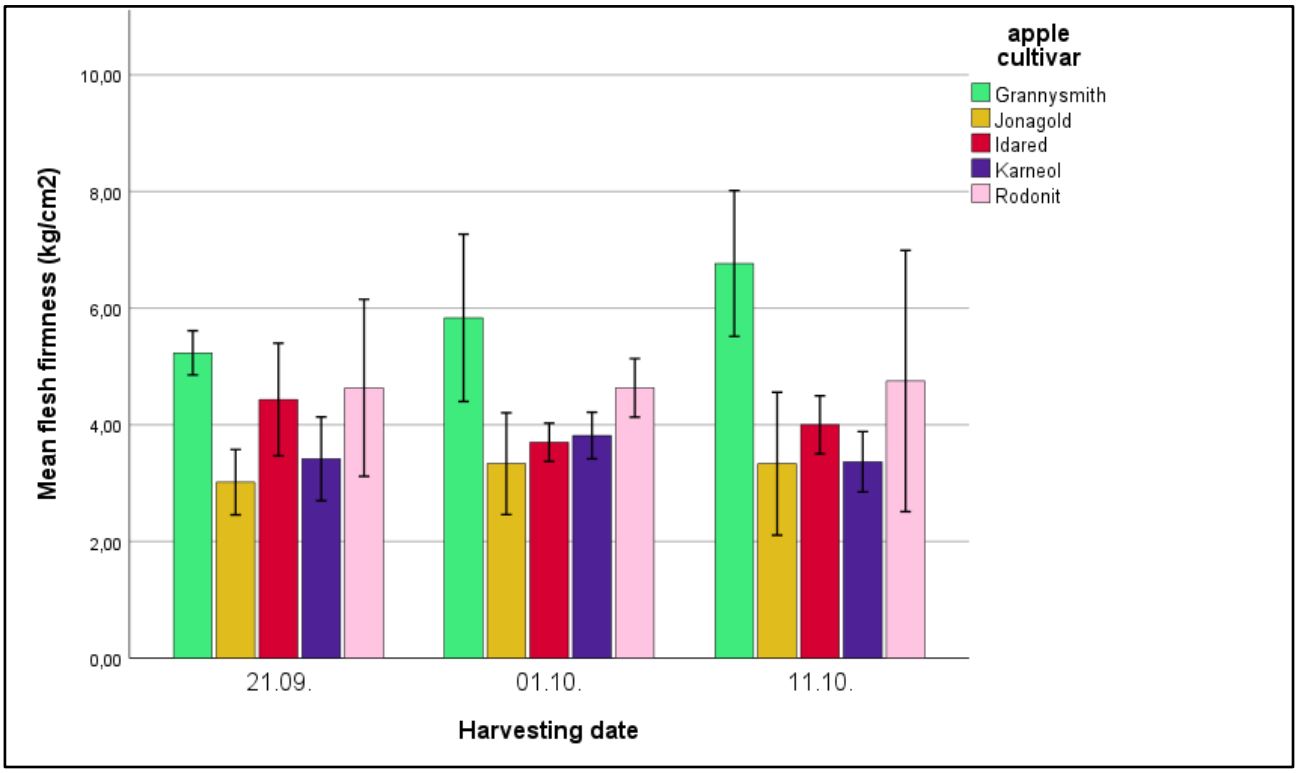


**Figure 5.6.1**: Clustered Range Bar chart of flesh firmness of the five apple cultivars by harvesting date and measured on 20.12. where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

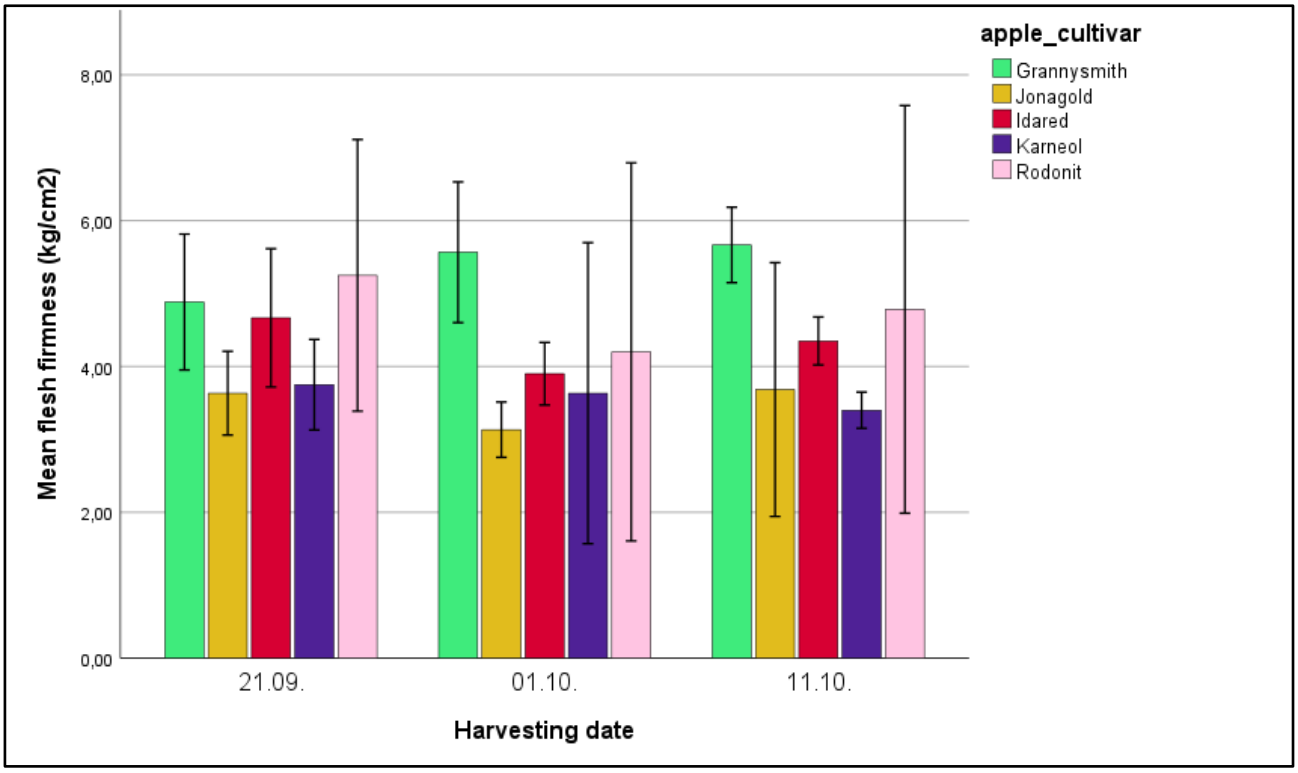


**Figure 5.6.2**: Clustered Range Bar chart of flesh firmness of the five apple cultivars by harvesting date and measured on 25.01. where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

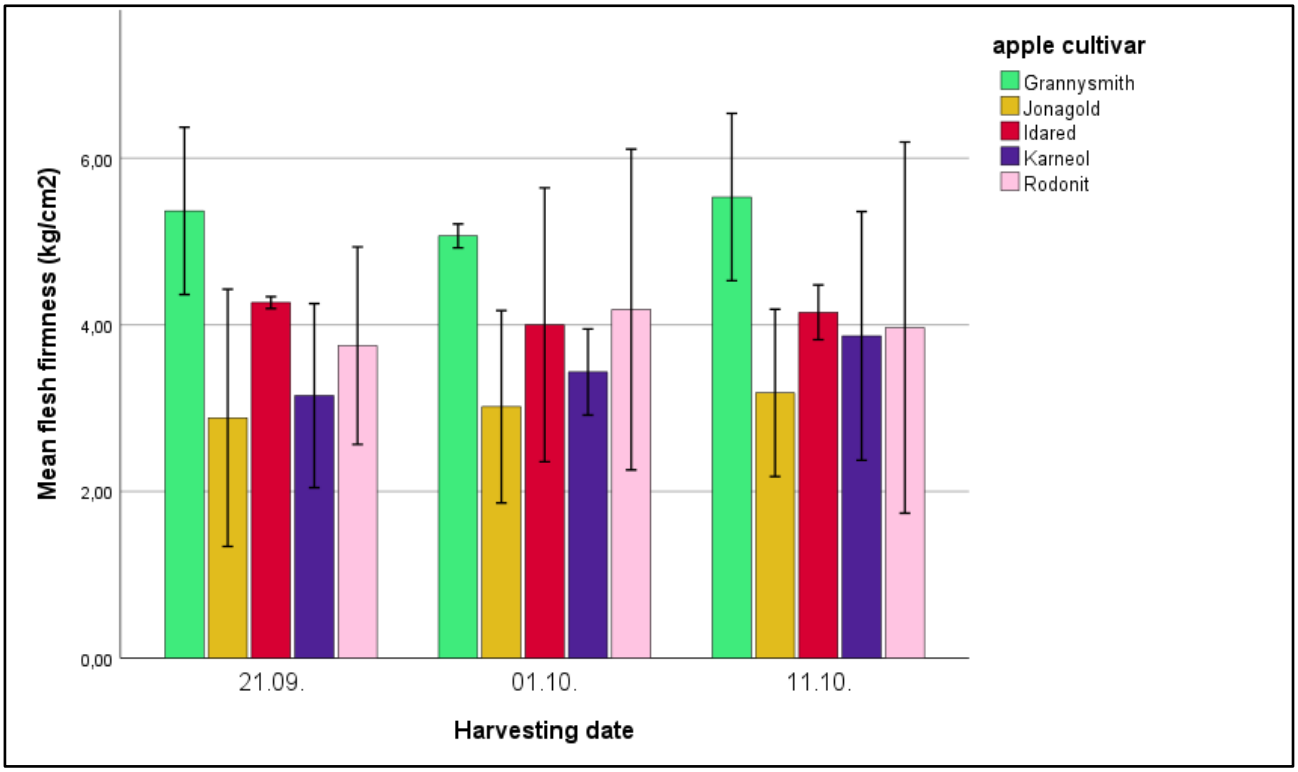


**Figure 5.6.3**: Clustered Range Bar chart of flesh firmness of the five apple cultivars by harvesting date and measured on 01.03. where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

The previous three figure (5.6.1-3) are showing the comparison of flesh firmness between the five chosen apple cultivars during storage. Each figure is one occasion of measurement (20.12.; 25.01; 01.03). Despite the long period of observation, the main trends are constant and the flesh firmness did not really changed compare to other cultivars. It can be seen very well, that no matter what, the 'Granny Smith' is having the greatest flesh firmness almost every time, except at the first harvest second measurement, when 'Rodonit' was showing some high numbers. However, 'Rodonit' was not able to maintain that level, and it dropped back to at 4 kg/cm$^2$ or below by the last measurement. If an apple cultivar with the third strongest flesh firmness should be chosen, it would be definitely 'Idared' based on the charts. The cultivar that is represented by red bars on the figures is around 4 kg/cm$^2$ throughout the observed storing period, sometimes above and sometimes below. 'Karneol' that is purple on the figures, couldn't get over the previously mentioned 4 kg/cm$^2$ at all. It was ranged withing 3 and 4 kg/cm$^2$. All in all, it can be assumed that from the observed cultivars, 'Jonagold' had the lowest flesh firmness. At the first two measurement, it was competing with 'Karneol', but by the last occasion, as it seen on the figure 5.6.3 'Karneol' had higher flesh firmness in the case of all the three harvests. The biggest difference based on a look on the charts is between 'Granny Smith' and 'Jonagold' at the first measurement last harvest and the first harvest at the last time of measure. It is important to mention that at many cases the standard deviations came really wide as it can be seen especially at the pink bars ('Rodonit'). Overall, it is assumed that if a costumer is rooting for buying apples that has a higher flesh firmness, then 'Granny Smith' could be advised or 'Rodonit' but the 'Rodonit' cannot maintain its firmness level so long as the other mentioned one. The date of harvest is not influencing that much the flesh firmness.

## 5.7 COMPARISON OF FLESH FIRMNESS OF THE FIVE APPLE CULTIVARS

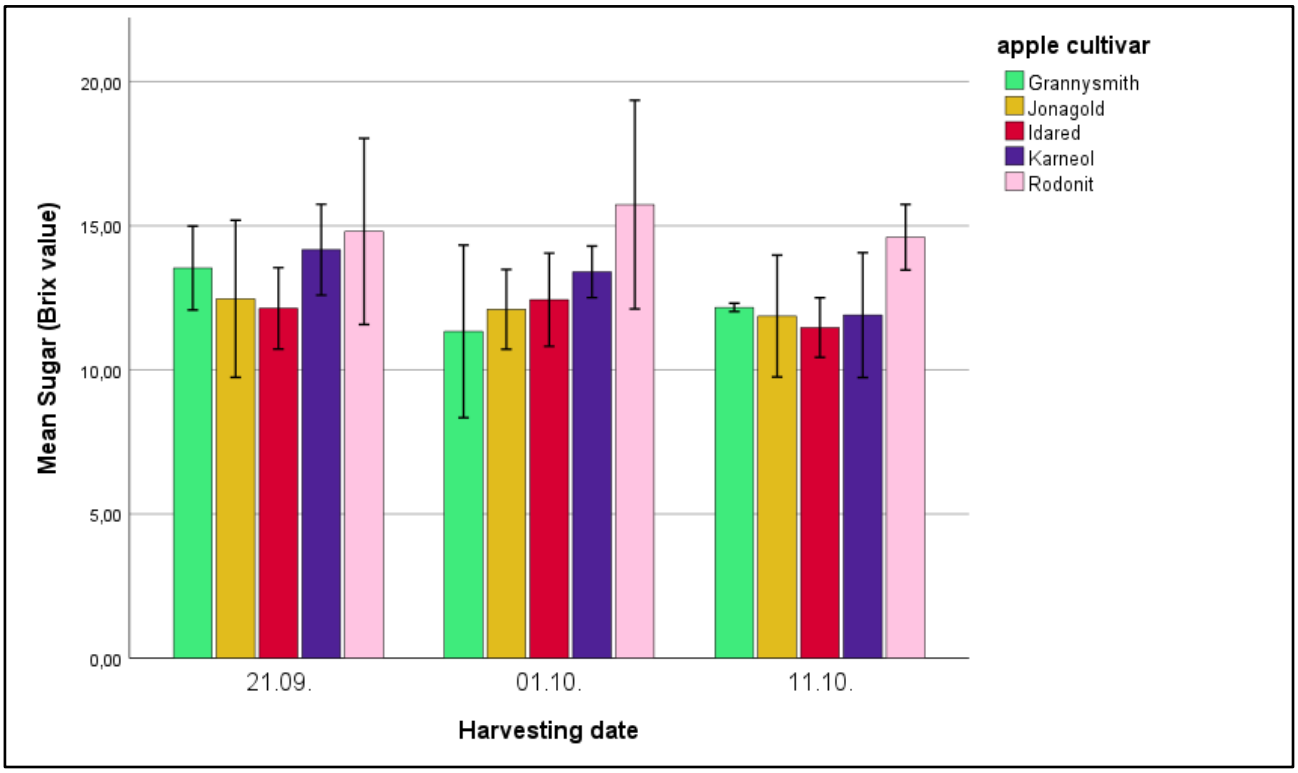


**Figure 5.7.1**: Clustered Range Bar chart of Brix value of the five apple cultivars by harvesting date and measured on 20.12. where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

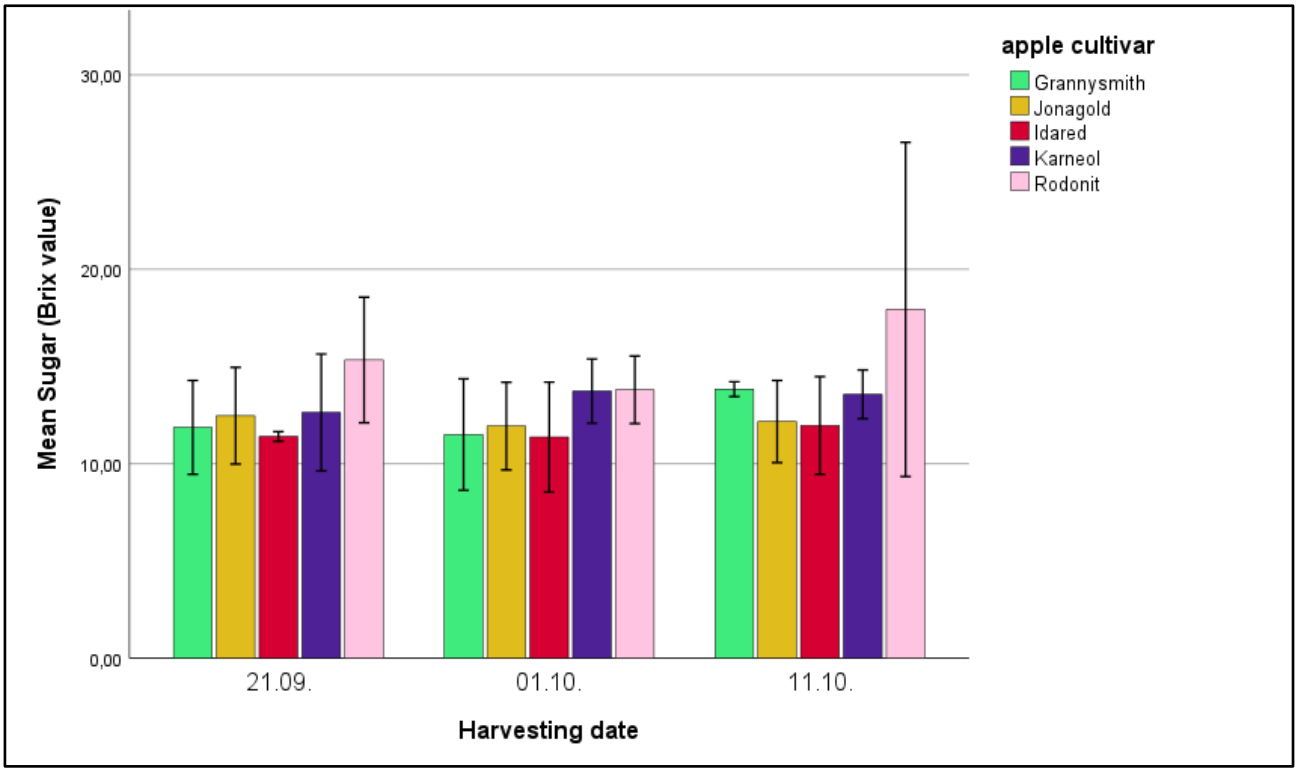


**Figure 5.7.2**: Clustered Range Bar chart of Brix value of the five apple cultivars by harvesting date and measured on 25.01. where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

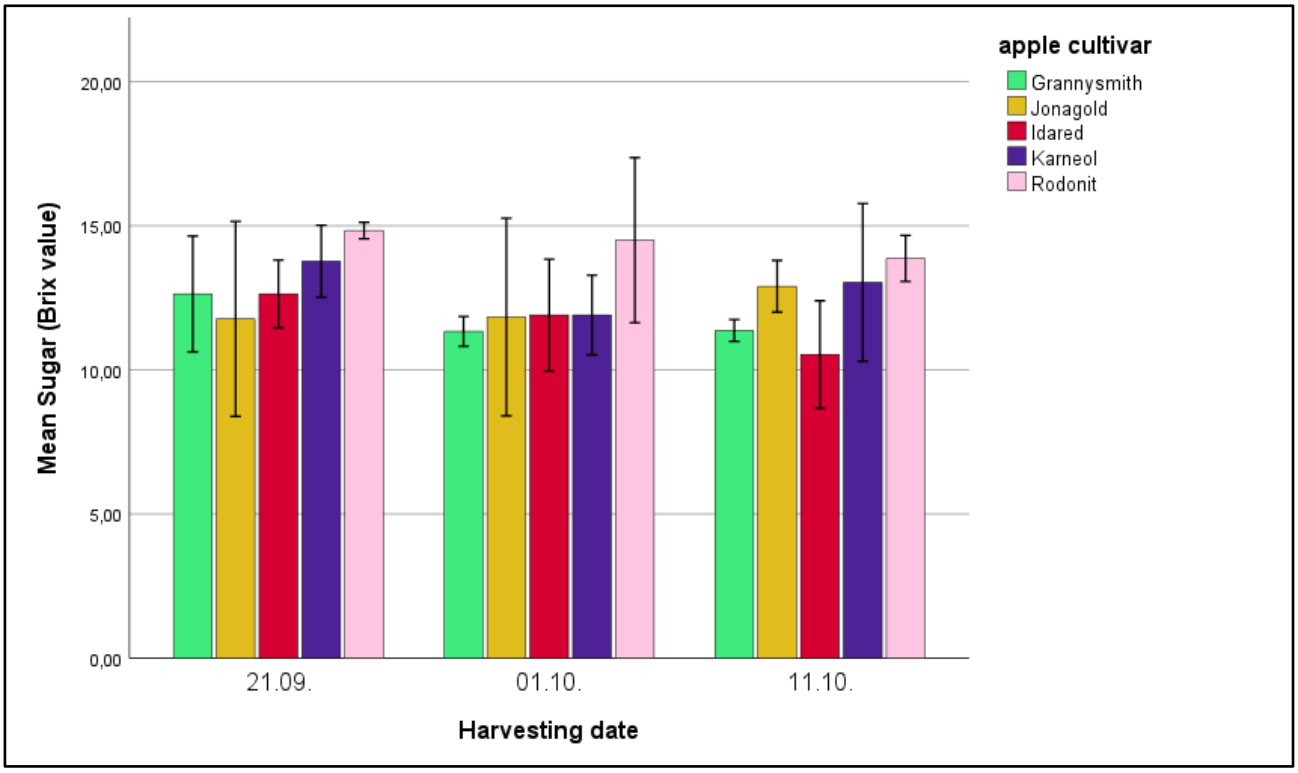


**Figure 5.7.3**: Clustered Range Bar chart of Brix value of the five apple cultivars by harvesting date and measured on 01.03. where the bars are representing the means of the flesh firmness and the whisker's lower end the minimum and the upper end the maximum.

On the pervious three figures, the sugar concentrations of different apple cultivars are represented. Each figure is from one-one occasion of measuring. By looking onto the charts, it can be seen very well, that overall, the pink bars are the highest in every case, so the 'Rodonit' had the highest amount of sucrose in 100g solution. The highest mean was resulted from the second measuring (25. January), when mean of 'Rodonit' from the last harvest was close around 18%. The second most sugary many times was 'Karneol' coloured purple on the charts. It got close to its pink neighbour bar at the first measurement from the first harvest, the second harvest's second measuring, and at the last measurement, both from the first and the third harvest. The Brix value of 'Granny Smith' was changing throughout the time of observation. The green bars (that are resembling 'Granny Smith') are sometimes the lowest like second harvest's first and third measuring, but from time to time 'Granny Smith' came second like at the first measurement where both the first and the third harvests' bars were relatively high, and also at the second occasion of sampling where the third harvest's sugar content was still the best behind 'Rodonit' among the apples that were harvested on the same day. Interestingly, the 'Jonagold' sugar concentrations are showing the opposite what was mentioned previously for 'Granny Smith', so as it is visible the bars of 'Jonagold' are constant and they are not really changing by the different harvest dates. On the first and second figure, so at the first two times of measuring the yellow bars are not really increasing nor decreasing compare to the others. It cannot be seen from the charts, but it is likely that all 'Jonagold' results from the first two measurement are positioned within the interval of 12-14%. Despite this non-changing trend, by the last measuring, the third and last harvest's sugar concentration increased compared to the first and second harvests' ones. There were 3 harvests, and all the three ones were measured three times, so totally nine measuring per cultivar. From the nine measurements 'Idared' had the lowest (not exclusively the lowest) Brix values six times. The only times when it was not the one with the lowest percentage was at the first measurement for the second harvest, and the last time of measure from the first and second harvest.

## 5.8 Comparison of apple cultivars' taste and consistency by organoleptic test

### 5.8.1 Evaluation of the flavour

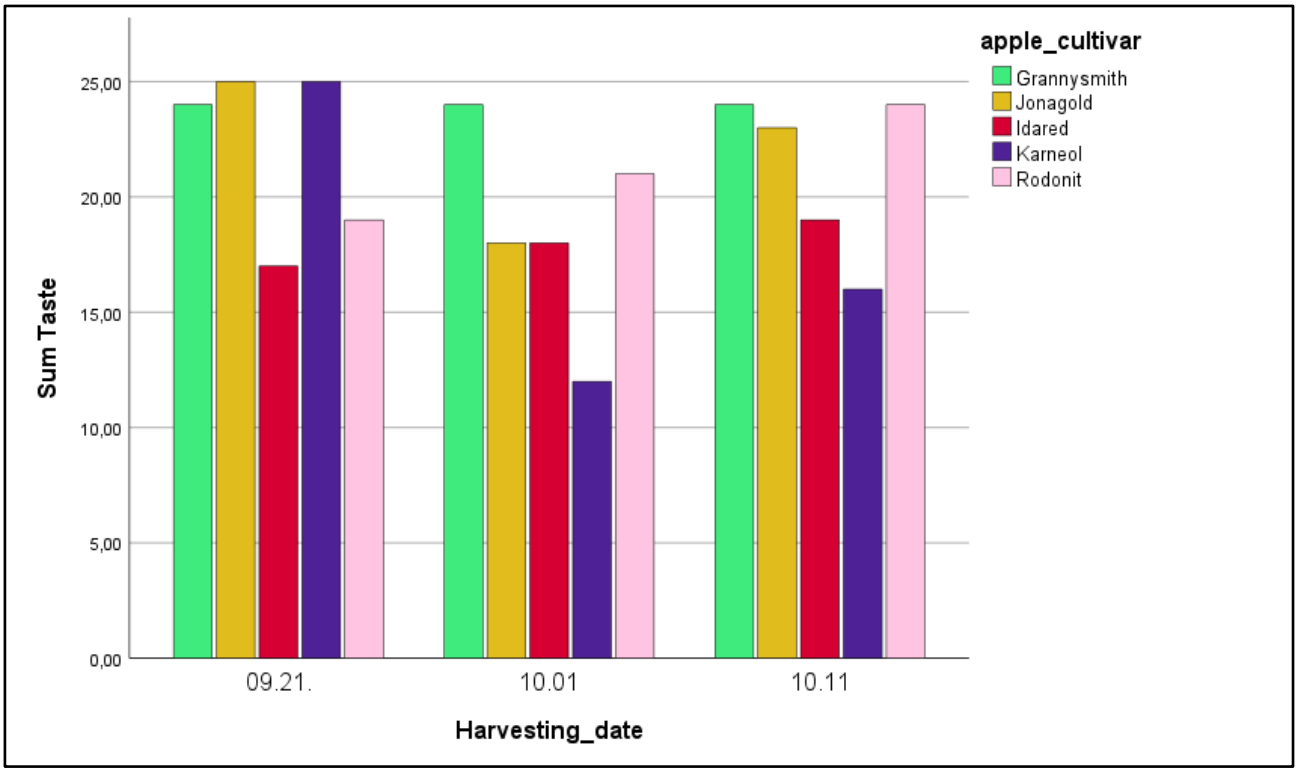


**Figure 5.8.1**: Clustered column chart of the total points received by organoleptic taste test, measured on 20.12.

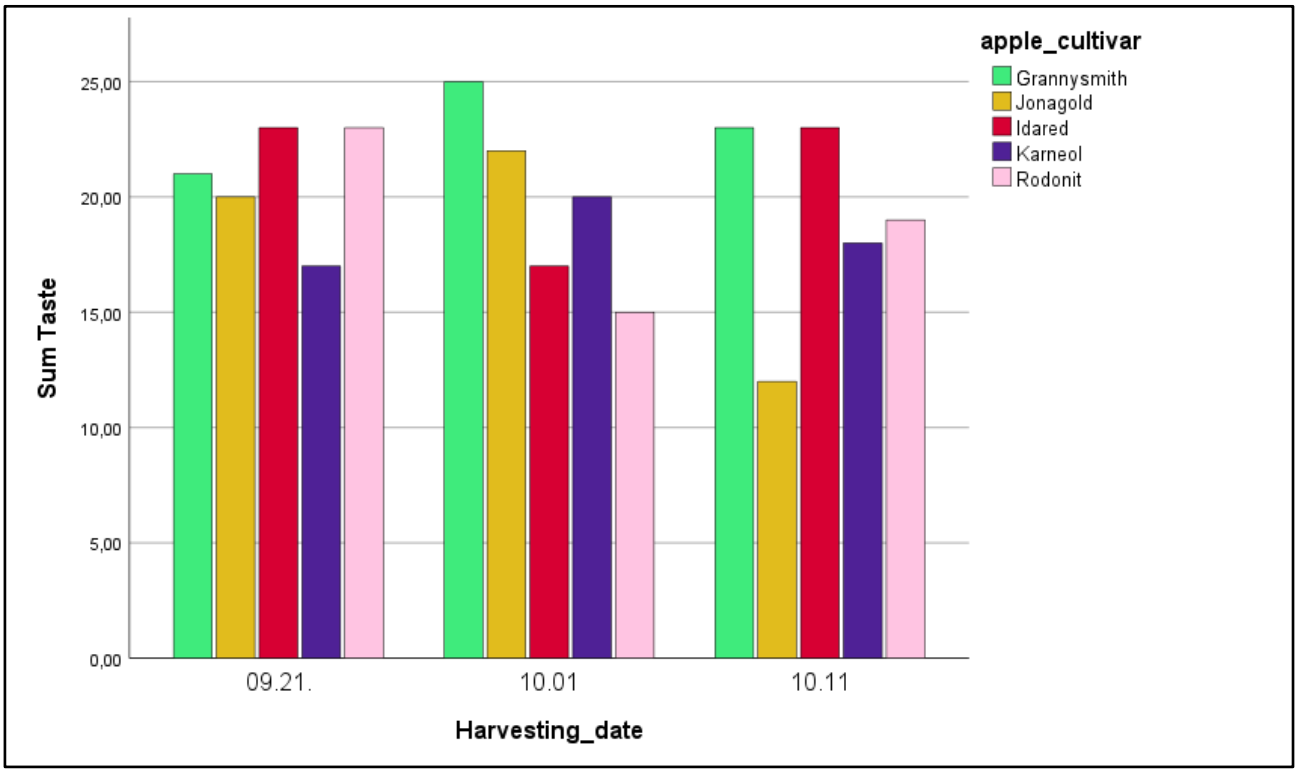


**Figure 5.8.2**: Clustered column chart of the total points received by organoleptic taste test, measured on 25.01.

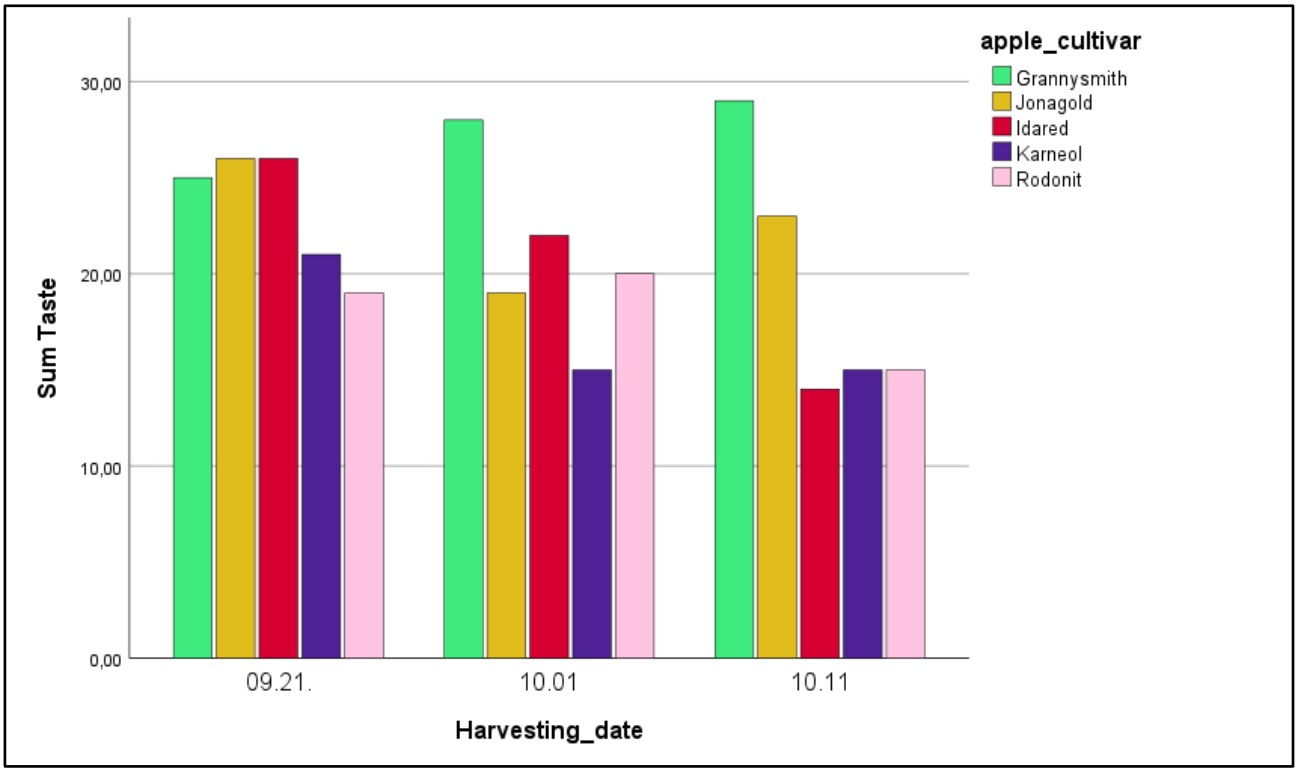


**Figure 5.8.3**: Clustered column chart of the total points received by organoleptic taste test, measured on 01.03.

This test was focussed by the flavour of the apple. Each time, the flavour was evaluated from 1 to 10 and then the points were summed. The different colours are referring to the different apple cultivars. From the charts on figures 5.8.1-3, it can be seen that ‘‘Granny Smith’’ has received the highest amount of points many times, or it finished in the top three every time at least. At the first measurement, from the first harvest ‘Jonagold’ and ‘Karneol’ received more points. However, ‘Karneol’ really dropped back later on, and from later harvests as well, as it could not overpass 20 points anymore, while ‘Granny Smith’ got more than 20 points every time. Also, the green apple is like a fine wine, as it received higher points later on the experiment at the second and the third time of measuring. By the last measure, the second and third harvest’s ‘Granny Smith’ almost got the maximum 30 points. What is more, the other cultivars could not maintain the same taste quality as during the measuring they got less points at one or more occasion of measuring. ‘Jonagold’ was at the top at one point but also it happened that samples from that cultivars were assumed as the worst tasting one among the cultivars. At the first time of measure the first and the third harvest both were among the best, so as at the last measurement where the samples from the first harvest received around 25-26 points, the same as ‘Idared’. On the other side, on the second measuring, the third harvest not only got the lowest amounts of points but also the difference between that and the other cultivars is well visible on figure 5.8.2. ‘Rodonit’ got more than 20 points only three times: At the first time of measure from the second and third harvest (it got 24 points, that is the best result of any other ‘Rodonit’ result out of the 9 result), and also at the next time of sampling, where the firstly harvested ‘Rodonit’ came first tied with ‘Idared’. Speaking of ‘Idared’, the classic cultivar was considered as the tastiest overall three times, but every time tied with another cultivar. These occasions were the second measuring date, where the first and the third harvest as well received more than 20 points. Furthermore, at the last measurement where the first harvest’s apples were awarded by around 25-26 points, that is the best that ‘Idared’ could get during the experiment.

## 5.9 EVALUATION BY CONSISTENCY

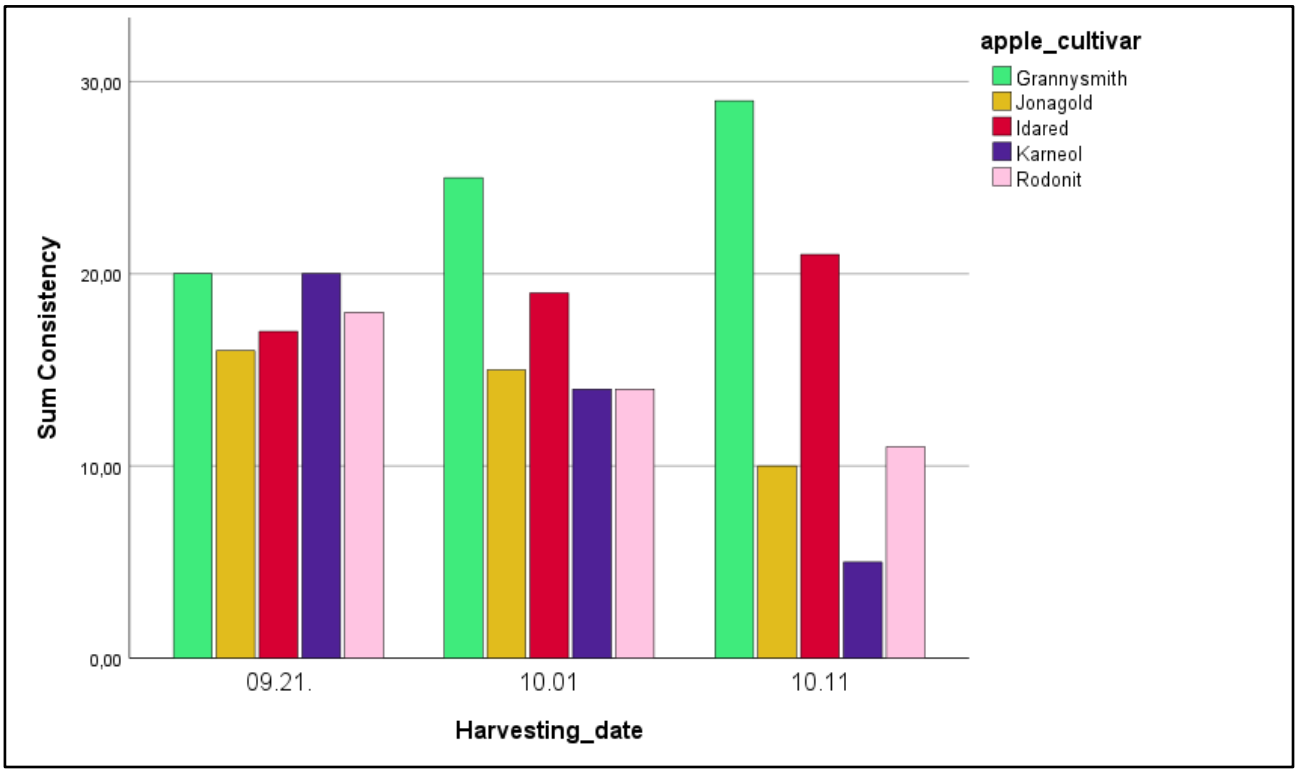


**Figure 5.9.1**: Clustered column chart of the total points received by organoleptic consistency test measured on 20.12

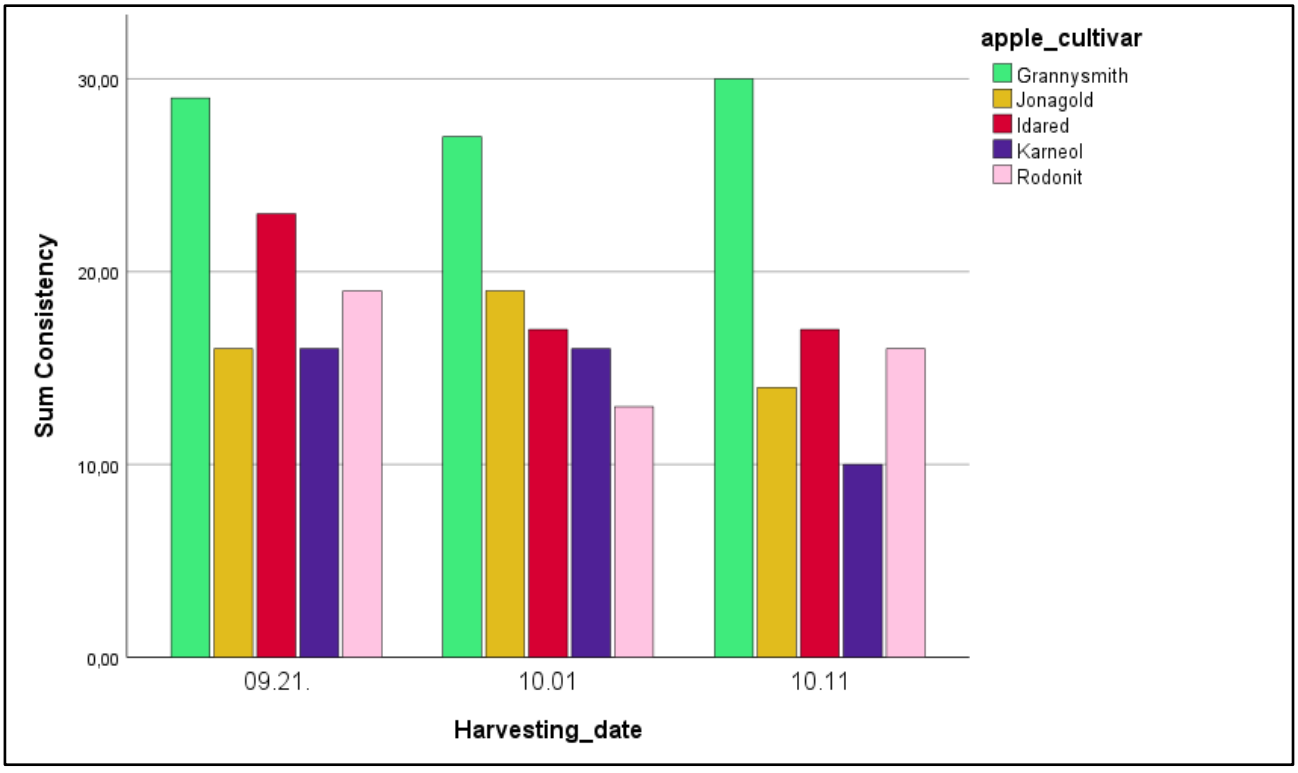


**Figure 5.9.2**: Clustered column chart of the total points received by organoleptic consistency test measured on 25.01.

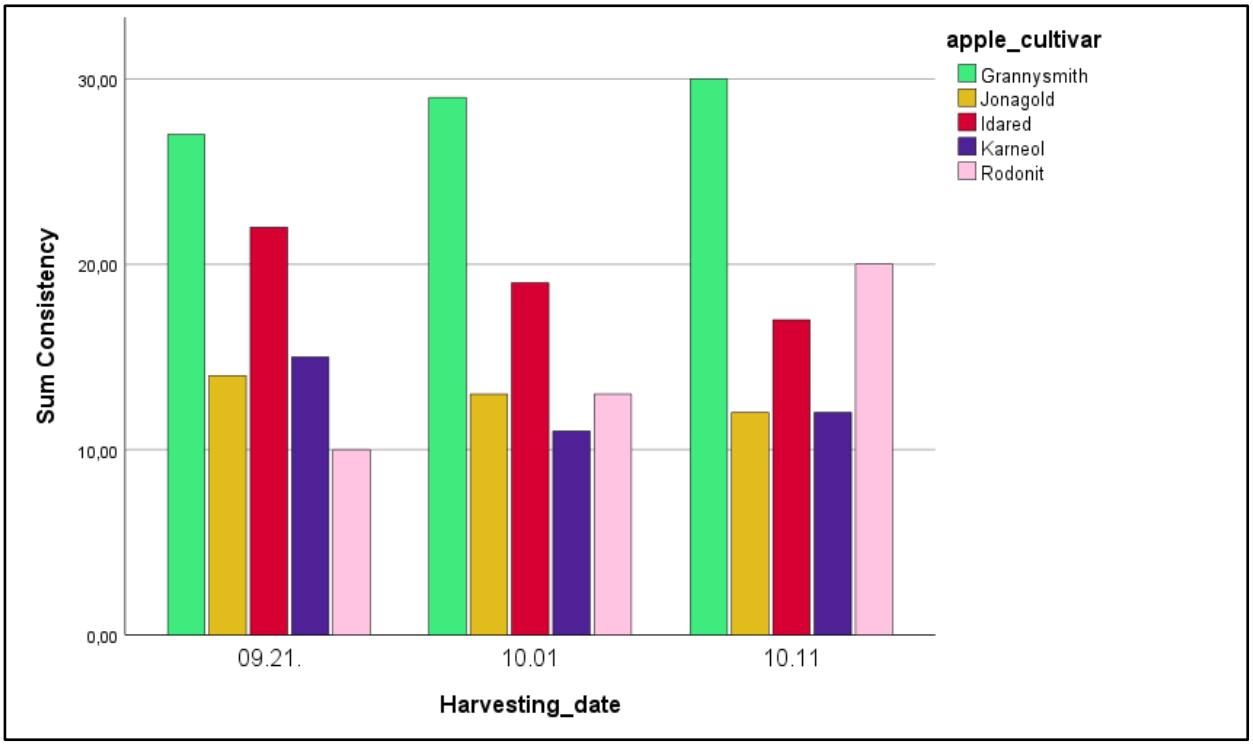


**Figure 5.9.3**: Clustered column chart of the total points received by organoleptic consistency test measured on 01.03

On figure 5.9.1; 5.9.2 and 5.9.3 the bar charts are showing the amounts of points that the apples with different harvesting dates received at each occasion of sampling for the inner consistency. 'Granny Smith' was a massive "winner" of this comparison. The only situation when the cultivar was not exclusively the best was at the first measurement where it was in tie with 'Karneol'. What is more, 'Granny Smith' got the maximum 30 points twice, at the second measuring from the third harvest and at the next time, from the same harvest. It nearly got the maximum points at the second time of measuring from the first harvest and from the second harvest at the last measurement. 'Jonagold' showed a decline more or less within the different harvests at some of the measuring, like it can be seen at the first and last measurement. Even at the second sampling, the second harvest received more points than the first harvest but the last harvest was worse. This particular outstanding that was just mentioned resulted the best points of 'Jonagold' out of the nine tests of 'Jonagold', but even that one could not received more than 20 points. In the case of 'Idared', the at the first time of measuring, the consistency was considered better as the apple was harvested later, but based on the results, it seems that the quality of the flesh and its consistency was declining during storage, as at the second and the third date of measure, the consistency is not increasing, but decreasing as the apple was harvested later. The charts are showing that 'Idared' came the runner-up behind 'Granny Smith' at many times. From 'Idared', the first harvest reached more than 20 points at the second and at the third measurement, while at the first sampling, third harvest got more than 20 points overall. Despite it only reached the 20 at the first measurement from the first harvest, for 'Karneol' this result is considered as the best from the consistency test. Later on, it was closer to 10 points than 20. In addition, it produced the lowest points among all the results. At the measuring on 20.12. the samples from the third harvest received around 5-6 points totally. Although, a clear tendency among the harvests is not recognisable, the consistency rather got worse by later dates of harvest. For 'Rodonit' the best points it got was 20 as well, but surprisingly it came at the last date of measure from the third harvest. Apart from that this cultivar was not receiving that much points, and it was more likely that the pink bars (which are the bars of 'Rodonit') are not that high compare to the other cultivars' bars at the from the same harvest at the same date of measure. The lowest points that 'Rodonit' got was 10 points which was given for the first harvest on 01.03. when the last occasion of sampling had happened. Based on the test, if a costumer is looking for apples that have a better flesh consistency, then 'Granny Smith' and 'Idared' is recommended, but other cultivars could be good depending on the time of the year.

### 5.10. EVALUATION OF THE SURVEY ABOUT THE TRENDS OF APPLE CONSUMPTION

The people were asked about the frequence of their apple consumption. Yearly, 37,3% consumes apples weekly, then 29% few times per week, 24% rarely. Only 9,7 eat apples in every day. Whereas, during the apple season, that is considered between September-December, the mentioned the percentages are shifted. Almost half of the people (48,2%) eat few times per week, 20,5% everyday, 19,3% weekly, 12% rarely. It can be seen that during the peak season the amount of people who eat apple daily is more than double, while few times per week consumption increased by 60%, the weekly consumption dropped by 51%. Those who eat apple rarely are decreased by 50% during the apple season. In addition, there was an option as never eat any apple, but none of the survey answerers belong to that group.

The volunteers who filled out the questionnaire, they also had to grade different parameters those could influence what kind of apple is bought. The following six factors were asked: Price, outlook, cultivar, flavour, storability and consistency. They were asked to give a mark from 1 to 5. 1 meant that parameter, is not important to take into account during apple buying, while 5 meant that it is an important factor. As the factors were graded, all of them got an aggregated point that was the sum of the grades. For example, the outlook got 324 points as 5 points was given by 31 people to whom this factor is very important, 23 individuals gave 4 points so it is important, but not extraordinarily, then 3 points by 21 persons, 2 points by 6 and only 2 members gave 1-1 point, as the appearance of apple is not important at all. In any case, the appearance of was thought as the most important buying factor for apple. However, the margin is only 2 points as the flavour got 322 points totally. The third most important factor is the consistency with 288 points, then price with 277 points, cultivar with 265 points and last but not least the storability of the apple has received 223 points.

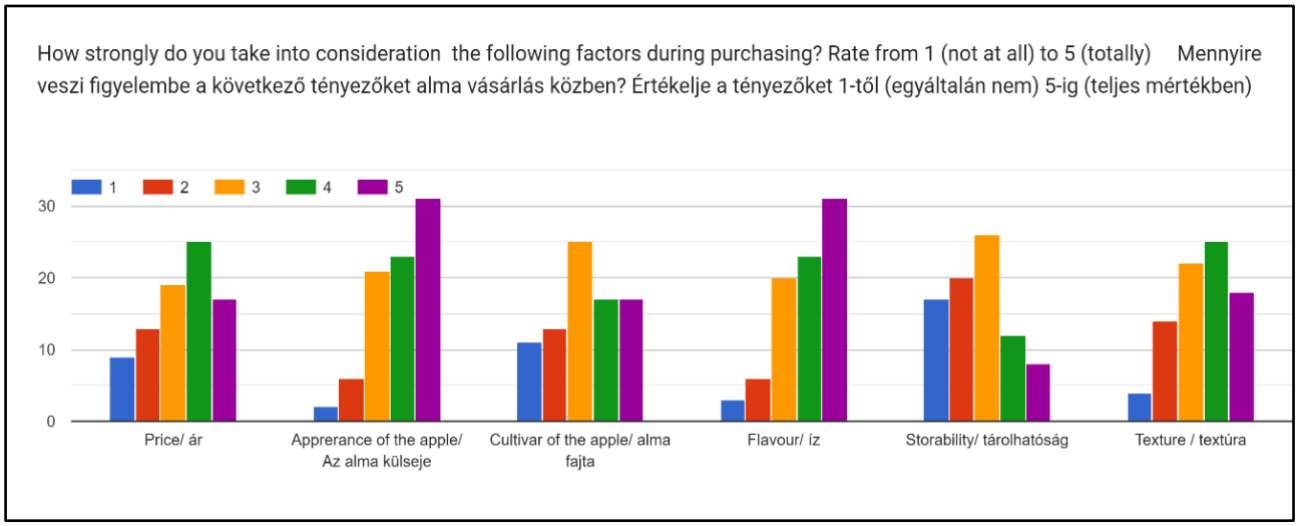


**Figure 5.10.1:** Bar chart of the result of evaluation of buying factors for apple on a scale from 1 to 5

On figure 5.10.1, it is seen that the appearance and the flavour was also prioritized by 31-31 individuals and 3 and 4 mark was given nearly by the same amount of people. As it was detailed the margin was only 2 points within these two factors. Price and consistency (texture on the chart) are rather considered as important as mark 4 has the highest bar on the chart. Although, for consistency the blue bar (mark 1) is way smaller than for the price. Cultivar of the apple is the most divided factor as there are no big difference between those to whom this is an important factor and to whom it is not. Moreover, there is an outstanding yellow bar (mark 3), as those who gave that grade, cultivar is neither important nor negligible. There is almost same amount of people who think the same about storability as for cultivar. Whereas, for this factor as it is represented on the figure x, there are more persons who believe that storability is not as important factor as the rest.

The questionnaire consisted questions about resistance apple cultivars. They were included as the other part of this thesis is about the storability of apple cultivars where resistance cultivars are discussed too. First of all, without any help for the answerers, it was asked whether they know what does that mean if an apple cultivar

(or any kind of crop) considered as resistant. It turned out that 45,8% of the answers showed awareness of what does resistance mean. The rest (54,2%) responded no. Following this question, and by explaining the term resistance, and detailing the aim of it in agriculture, it was asked whether the mindfulness of resistance would influence which apple cultivar is preferred next time when apple is bought. 50,6% of the answers were about that it would absolutely influence, 22,9% are rather be influenced, 24,1% are neutral. Only 1,2%-1,2% answered rather not to be influenced or not to be influenced at all. By observing the previously written percentages, it is assumed that by a good marketing, new apple cultivars, that have resistance or tolerance against any disease, those cultivars could breakthrough the market. The demand could decrease of old cultivars that are popular but less feasible to produce as they are more sensitive to diseases. Consumers are still conservative about their cultivar preference (if it is taken into account), and the demand of old cultivars is constant, as buyers are not keen on to change their apple buying habits. This topic about the cultivar preference opens the next topic that was part of the survey.

People were asked to choose out every apple cultivar from the list, that they have ever heard of. The list enumerated 17 cultivars. The cultivars on the list are the most common cultivars on the Hungarian market, some good old cultivars, plus some new cultivars (that have tolerance either resistance).

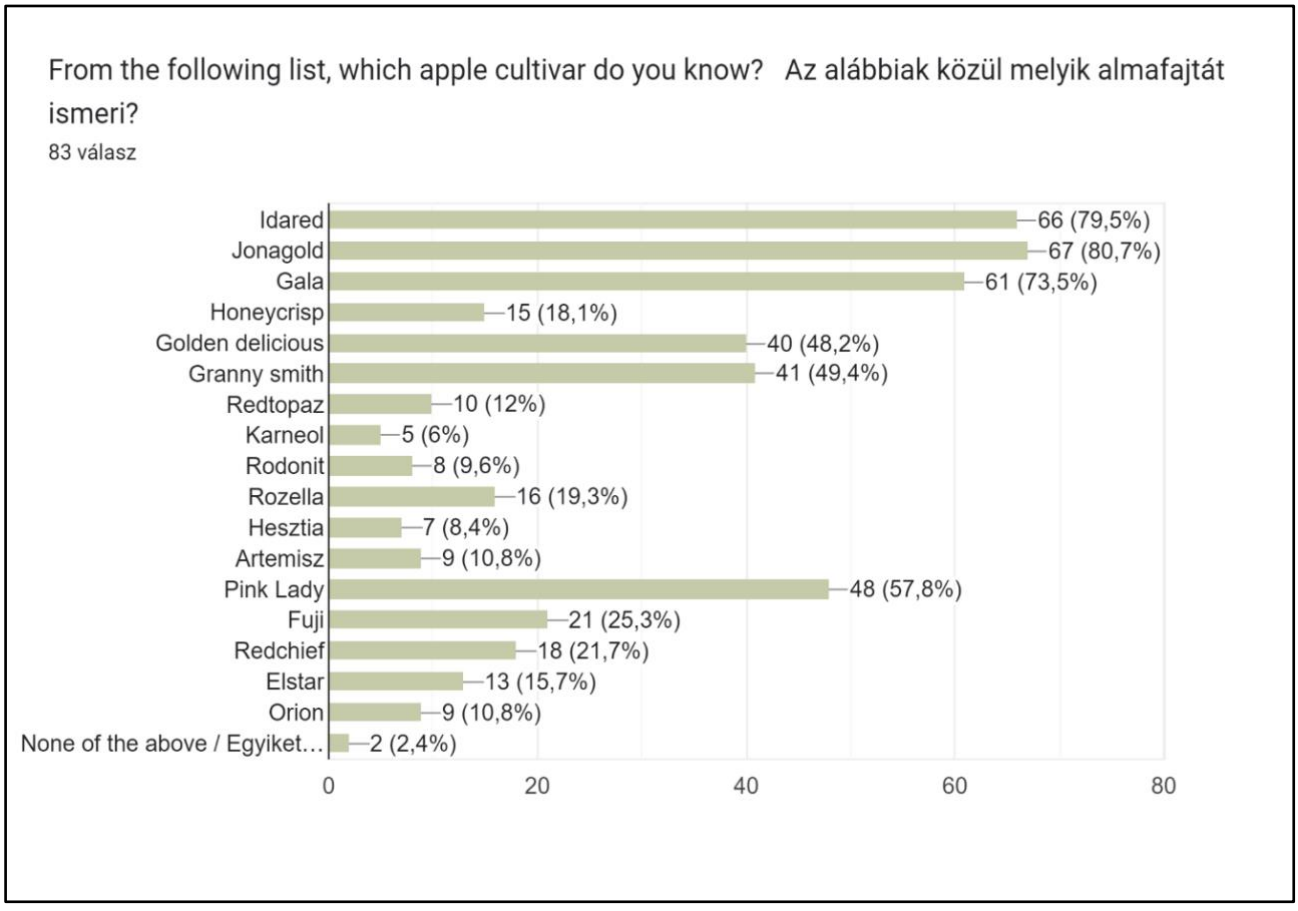


**Figure 5.10.2:** Horizontal bar chart represents the publicity of cultivars among the answerers.

On figure 5.10.2, it is seen that 'Idared', 'Jonagold' and 'Gala' are the top three most popular cultivars. 'Jonagold' was known by more than 80% of the individuals. The top three cultivar is followed by 'Pink Lady', that is a club cultivar, and it has a huge marketing, and it can be found in the supermarkets throughout the year. ''Granny Smith'' and 'Golden Delicious' has nearly the same percentage. The bottom of the list is by 'Karneol', 'Rodonit', 'Hesztia' and 'Artemisz'. These cultivars are the new cultivars, and they are Hungarian ones, so an imported apple that is sold in the markets could not be one of these cultivars. 'Redchief', 'Fuji' and 'Rozella' are not Hungarian cultivars, but either as imported or as local (produced in Hungary) could be found on the market. 'Honeycrisp' is considered rather as an American cultivar, and not common on Hungarian Market.

If a cultivar is known by its name, it does not mean that is actually consumed. That is why the next question is about the preference within cultivars. At this question, it was possible to add any other cultivar that might not on the list. At this question the percentages were nearly the same as at the previous question, but 'Idared' had the highest percentage of preference. Some new cultivars were added as extra answers like 'Mutsu', 'Starking', 'Redlove', 'Braeburn'.

As it was discussed before in this chapter flavour is an important characteristic of apple, that humans pay attention for. Despite it is an important factor, it is already divided what flavour is preferred. That is why everyone who answered to this form, had to position him/herself on a scale from 1 to 5, where 1 means sour is preferred 5 means apple is preferred if it is sweet.

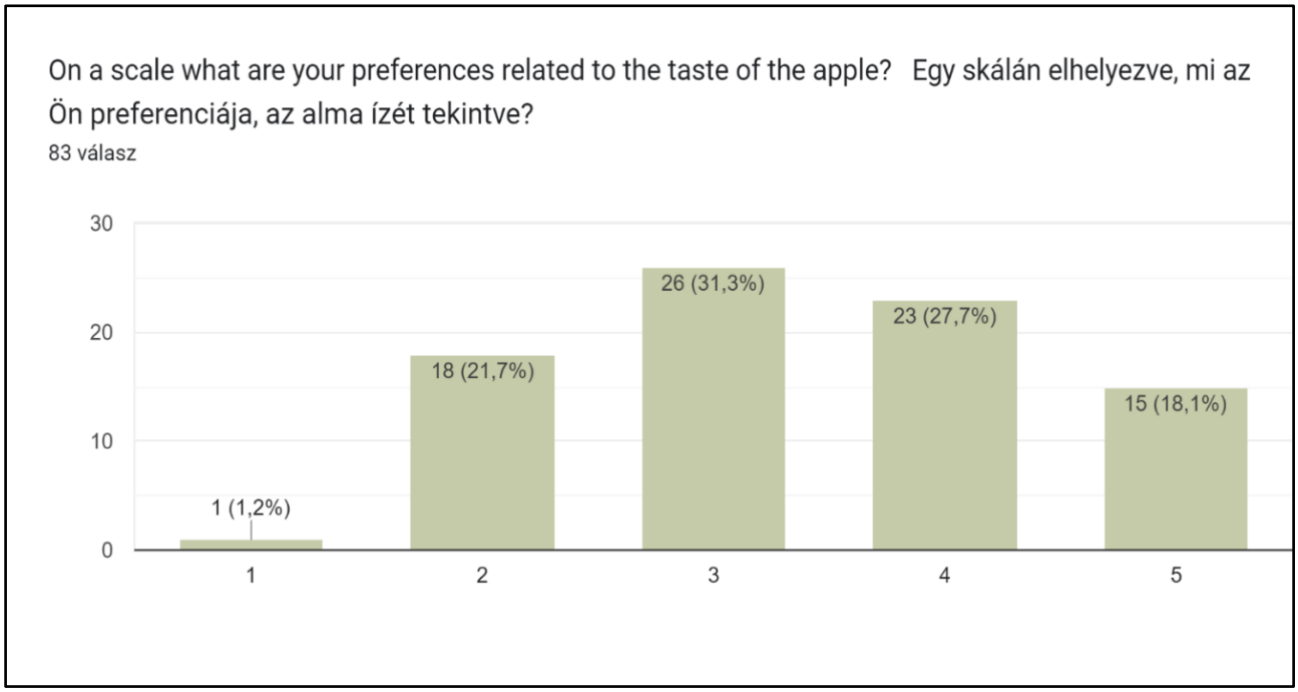


**Figure 5.10.3:** Bar chart of distribution of flavour preference.

On figure 5.10.3, it is showed that the highest percentage with 31,3% are those who are assume themselves neither sour nor sweet apple fan. Slightly less people (27,7%) are in the group where sweet apple is considered rather favourite. 18,1% of the answers are on the side of sweet flavour is the best. 21,7% says that sour flavour is preferably better. Lastly, only 1,2% considers sour flavoured apple the best.

It is very encouraging if costumers are aware of apple cultivars, aware of their preferences, opened for new cultivars. However, it is interesting to know, whether they are on to do any extra effort to buy apple. For instance, would consumers take extra journey to buy apple, or there is not much hope saving that they buy it in supermarkets together with every good they need. That is why it was observed whether they would travel more only to by apple.

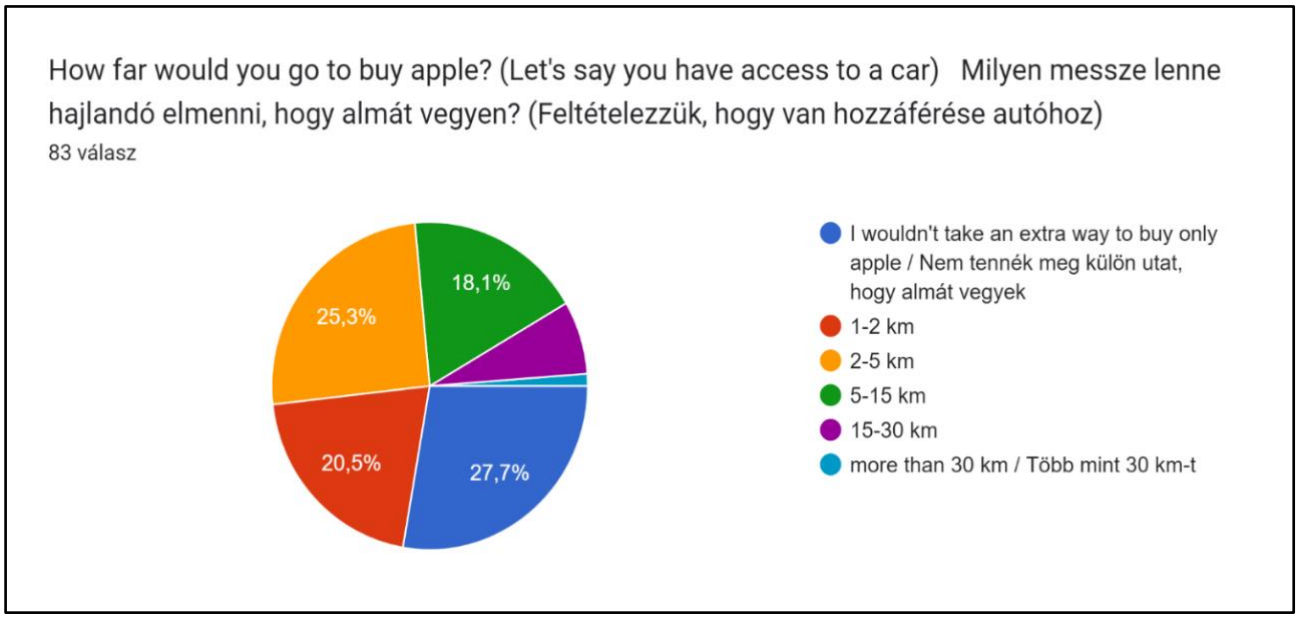


**Figure 5.10.4:** Pie chart of distribution about the willingness of extra travel to by apple

27,7% would not take any extra way to buy apple, as it can be seen on figure 5.10.4. 20,5% would take 1-2 km extra. This distance cannot be considered as real plus effort to buy apple. 25,3% would take 2-5 km. Normally, a distance like this could be enough to reach a farmers' market, a greengrocer or a vending machine where local products are sold. This is even more true for that 18,1% who are willing to travel at least 5-15 km more to buy apple. Slightly more than 7% would get into the car to buy apple if it is within 30 km. Those percentage who would travel more than 30 km is almost negligible, but there is approximately 1%.

# 6. CONCLUSIONS (DISCUSSION OF RESULTS)

## 6.1. DISCUSSION OF THE FLESH FIRMNESS AND BRIX VALUE CHANGE

The flesh firmness has showed quite interesting results, and not particularly what was excepted from previous measurements. The test was carried out like other flesh firmness related tests, as it is made usually with several kind of tools, that are either manual or semiautomatic. (Grotte et al., 2001). Although, the flesh firmness is having more similarities, and overall statements can be discussed. The flesh firmness normally had a lower quality throughout the period of observation, during storing. For a further experiment, it would be nice to also measure the parameters right at harvest, so to see what the original value was, right at the start of the storage. What is more the results of the five cultivars are showing different changes compare to each other. Most of them were decreasing over time, however, there are a few occasions where the testing resulted increase by the end of the research. For a later experiment it would be useful to sample more at each measuring to receive a more accurate result. Without doubt the low storing temperature should had a positive effect on keeping the flesh firmness on a higher level. If the apple would have been kept on room temperature during storage, the results should had been lower (Johnston et al., 2001).

The Brix value has resulted likely similar results such as the flesh firmness in a way of overall change from the first measuring till the last. Again, as it was mentioned in the previous paragraph, that another sampling right at harvest would have been a good idea and a helpful data. Some of the harvests showed increase over time while some of them showed the opposite trends. Whereas, only in a few cases where there any significant difference between the sugar concentration. For another research more sample would have been useful here as well. Obviously, there were differences between the cultivars, as they are having different characteristics.

## 6.2. DISCUSSION OF THE APPLE CONSUMPTION TRENDS

The survey that was served for the research was filled out by 83 people. The form gave an overview about that the costumers are still preferring the old cultivars like ‘Idared’ and ‘Jonagold’. However, on the other side of the table there are those ones who are not really taking care about what cultivar are they purchasing, “apple is apple”. For these costumers and basically for everyone else, the price of the available apple is quite important but not an exclusive factor. Especially by knowing the fact that apple is one of the cheapest and the most easily available fruit on the market all year round in Hungary and in other European and developed countries, consumers will buy apple in any case, as they are demanding to eat some kinds of fruits. In average a Hungarian consumes 13-15 kg of apples nowadays based on the data of KSH. This amount is an increase compared to the previous years, where the average was around 11-12 kg per year per person. Unfortunately, as it was also mentioned previously at the literature reviews, Hungary could be able to cover its apple necessity most likely, but in reality, it is not possible. This is because of other countries good marketing strategy, and the unstable yield of the Hungarian orchards. The price of apple in the stores are different based on season, size of the shop, cultivar of apple, as club cultivars like ‘Pink Lady’ or ‘Evelina’ cost more due to their brand. Approximately it is around 400-600 HUF/kg in grocery stores. However, based on previously discussed articles in Hungary the farmers can sell it only for 140-160 HUF/kg, so a logical question comes that how is it so expensive for costumers relatively? That additional cost is all because of suppliers and wholesalers who buy apple from the farmers in enormous amount. All these facts are important to mention as costumers are willing to look up local farmers, shops where they can probably buy apple on a lower price, but if not than still the apple comes from the neighbourhood, so at the end of the day, the local entrepreneurships and farms are supported. In the survey nearly ¾ of the people claimed to take an extra way (even if is only 1-2 km extra) to visit a shop where they can buy apple. Around ¼ of the individuals would travel more than 5 km to buy apple. So, I assume that by good marketing, available options and educating people about the new cultivars, it would be possible for new apple cultivars to break through the market and costumers would buy it over older already known and consumed cultivars. On the sour-sweet flavour scale much of the people are positioning themselves more to the sweet, but there are those who eat sourish apple preferably.

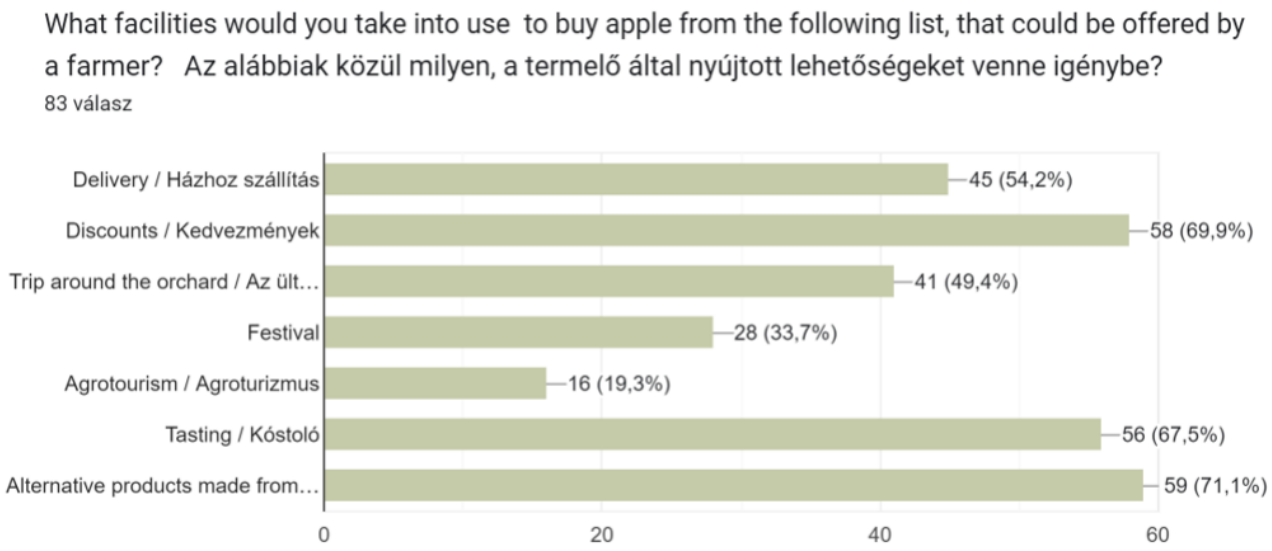


**Figure 6.2:** Willingness of costumers to use alternative services offered by farmers

Despite the good quality of the crop, in today's world it is not enough to offer "only" good crop, in our case apple. There are several ways how a producer can attract more buyer. In the survey the answerers should relatively high interest to alternative products that are made from the main, primary product. For instance, apple juice, chips, jam, vinegar. Every crop has its own characteristics possibilities. Discounts are always a huge influencing factor no matter what is consumed. In addition, tastings can be a good way of convincing individuals of buying new yet untried cultivars. Delivering and farm introduction had a mix attractiveness based on the survey, although based on own experiences delivery can improve the selling massively, as it reaches costumers that are unable to shop in person.

# 7. SUMMARY

This thesis work was served to discuss two things related to apple production. In one hand what are the differences between the flesh firmness, Brix value of the five selected cultivars, accompanied with an organoleptic flavour and consistency test. On the other hand, to receive an overview of costumers' behaviour and preferences about apple consumption. For the experiment the results were quite interesting and not that clear differences and changes that I was predicting and expecting previously. The changes didn't happen correlated and there were several unexpected increases and decreases over time. For a next time more than three variables could be nice to get a much more exact result.

In the case of the survey, it was nice to see that amount of people who helped by filling out the form and share it in their social media platforms to reach more people. Luckily the received answers were quite diverse, although it is seen that most active generation was my generation as most of the people who were reached were from that same generation. The answers also referred to the phenomena that at the end of the day, price is one of the most considered factors to consider during any purchase. So, it is very important to say that no matter what kind of apple is produced, in how developed and intensive orchard, if the price is found to high by the costumers, they will tend to buy other alternatives despite the truth that apple is one if not the cheapest fruit on the market, at least in regions where it is massively produced. It must be added that the final price is not primarily decided by the farmer, as the crop most of the times goes through one or more suppliers.

In conclusion, apple production sector must face with the same challenges as other sectors on agriculture. The climate change is forcing breeders to come up with new cultivars that can adapt to the new and unpredictable conditions. Cultivars need to tolerate lack of water, heat and cold waves, late spring frosts. Furthermore, automatization is necessary as well to cover the labour shortage and to make processes faster, smoother, and digitally followable as well.

All in all, apple cultivars are like species in the nature, they are going through evolution and the strongest, preferred and most adaptable ones will survive but nothing last forever.

# 8. ACKNOWLEDGMENTS

I would like to thank for Laszlo Szalay PhD for helping and guiding my work with this thesis. His advice and proposals were crucial for create the final document. Particularly his help by explaining what the required standards from the university are. I could request a consultation with him anytime, so I really appreciate all the time and effort that he gave me. I would like to express my grate for the Department of Fruit Growing by providing measuring tools for my experiments. Furthermore, I would like to highlight all the 83 people who took their time to fill out the survey that was involved in this thesis. The aggregation of their answers made a very interesting outcome. Last, but not least I would like to thank for my family's agricultural business, Horvath Mezogazdasag. My family offered place to execute my experiment.

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# ATTACHMENTS

Appendix 1.

***Post-Hoc tests of means of flesh firmness of ''Granny Smith'' by harvesting date***

**Multiple Comparisons**

Dependent Variable: flesh_firmness

LSD

| (I) Harvesting_date | (J) Harvesting_date | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 21.09. | 01.10. | -,3278 | ,17743 | ,081 | -,7005 | ,0450 |
| | 11.10. | -,8278* | ,17743 | <,001 | -1,2005 | -,4550 |
| 01.10. | 21.09. | ,3278 | ,17743 | ,081 | -,0450 | ,7005 |
| | 11.10. | -,5000* | ,17743 | ,011 | -,8728 | -,1272 |
| 11.10. | 21.09. | ,8278* | ,17743 | <,001 | ,4550 | 1,2005 |
| | 01.10. | ,5000* | ,17743 | ,011 | ,1272 | ,8728 |

Based on observed means.
The error term is Mean Square(Error) = ,142.

*. The mean difference is significant at the ,05 level.

***Post-Hoc test of ''Granny Smith''s means of sugar content between different harvesting dates***

**Multiple Comparisons**

Dependent Variable: sugar

LSD

| (I) Harvesting_date | (J) Harvesting_date | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 21.09 | 01.10. | 1,2889* | ,34486 | ,002 | ,5644 | 2,0134 |
| | 11.10. | ,2222 | ,34486 | ,527 | -,5023 | ,9468 |
| 01.10. | 21.09 | -1,2889* | ,34486 | ,002 | -2,0134 | -,5644 |
| | 11.10. | -1,0667* | ,34486 | ,006 | -1,7912 | -,3421 |
| 11.10. | 21.09 | -,2222 | ,34486 | ,527 | -,9468 | ,5023 |
| | 01.10. | 1,0667* | ,34486 | ,006 | ,3421 | 1,7912 |

Based on observed means.
The error term is Mean Square(Error) = ,535.

*. The mean difference is significant at the ,05 level.

Appendix 2.

***Post-Hoc test of 'Idared' means of flesh firmness by measuring date***

**Multiple Comparisons**

Dependent Variable: flesh_firmness

LSD

| (I) Harvesting_date | (J) Harvesting_date | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 21.09. | 01.10. | ,5889* | ,14551 | <,001 | ,2832 | ,8946 |
| | 11.10. | ,2889 | ,14551 | ,063 | -,0168 | ,5946 |
| 01.10. | 21.09. | -,5889* | ,14551 | <,001 | -,8946 | -,2832 |
| | 11.10. | -,3000 | ,14551 | ,054 | -,6057 | ,0057 |
| 11.10. | 21.09. | -,2889 | ,14551 | ,063 | -,5946 | ,0168 |
| | 01.10. | ,3000 | ,14551 | ,054 | -,0057 | ,6057 |

Based on observed means.
The error term is Mean Square(Error) = ,095.

*. The mean difference is significant at the ,05 level.

***Post-Hoc test of 'Idared''s sugar content means between different harvesting dates***

**Multiple Comparisons**

Dependent Variable: Sugar

LSD

| (I) Harvesting_date | (J) Harvesting_date | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 21.09. | 01.10. | ,1556 | ,33860 | ,651 | -,5558 | ,8669 |
| | 11.10. | ,7333* | ,33860 | ,044 | ,0220 | 1,4447 |
| 01.10. | 21.09. | -,1556 | ,33860 | ,651 | -,8669 | ,5558 |
| | 11.10. | ,5778 | ,33860 | ,105 | -,1336 | 1,2892 |
| 11.10. | 21.09. | -,7333* | ,33860 | ,044 | -1,4447 | -,0220 |
| | 01.10. | -,5778 | ,33860 | ,105 | -1,2892 | ,1336 |

Based on observed means.
The error term is Mean Square(Error) = ,516.

*. The mean difference is significant at the ,05 level.

Appendix 3.

***Post-Hoc test of 'Karneol's' sugar content means between different harvest times at the first measurement occasion.***

**Multiple Comparisons**

Dependent Variable: Sugar

LSD

| (I) Harvesting_date | (J) Harvesting_date | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 21.09. | 01.10. | ,7667 | ,53610 | ,203 | -,5451 | 2,0785 |
| | 11.10. | 2,2667* | ,53610 | ,006 | ,9549 | 3,5785 |
| 01.10. | 21.09. | -,7667 | ,53610 | ,203 | -2,0785 | ,5451 |
| | 11.10. | 1,5000* | ,53610 | ,031 | ,1882 | 2,8118 |
| 11.10. | 21.09. | -2,2667* | ,53610 | ,006 | -3,5785 | -,9549 |
| | 01.10. | -1,5000* | ,53610 | ,031 | -2,8118 | -,1882 |

Based on observed means.
The error term is Mean Square(Error) = ,431.

*. The mean difference is significant at the ,05 level.

***Post-Hoc test of 'Karneol's' sugar content means between different harvest times at the third measurement occasion.***

**Multiple Comparisons**

Dependent Variable: Sugar

LSD

| (I) Harvesting_date | (J) Harvesting_date | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 21.09. | 01.10. | 1,8667* | ,62834 | ,025 | ,3292 | 3,4042 |
| | 11.10. | ,7333 | ,62834 | ,287 | -,8042 | 2,2708 |
| 01.10. | 21.09. | -1,8667* | ,62834 | ,025 | -3,4042 | -,3292 |
| | 11.10. | -1,1333 | ,62834 | ,121 | -2,6708 | ,4042 |
| 11.10. | 21.09. | -,7333 | ,62834 | ,287 | -2,2708 | ,8042 |
| | 01.10. | 1,1333 | ,62834 | ,121 | -,4042 | 2,6708 |

Based on observed means.
The error term is Mean Square(Error) = ,592.

*. The mean difference is significant at the ,05 level.

appendix 4.

***Post-Hoc test of 'Rodonit's' sugar content means between different measuring occasions of the third harvest.***

**Multiple Comparisons**

Dependent Variable: Sugar

LSD

| (I) measuring_date | (J) measuring_date | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 20.12. | 25.01. | -3,3333 | 1,65171 | ,090 | -7,3749 | ,7083 |
| | 01.03. | ,7333 | 1,65171 | ,673 | -3,3083 | 4,7749 |
| 25.01. | 20.12. | 3,3333 | 1,65171 | ,090 | -,7083 | 7,3749 |
| | 01.03. | 4,0667* | 1,65171 | ,049 | ,0251 | 8,1083 |
| 01.03. | 20.12. | -,7333 | 1,65171 | ,673 | -4,7749 | 3,3083 |
| | 25.01. | -4,0667* | 1,65171 | ,049 | -8,1083 | -,0251 |

Based on observed means.

The error term is Mean Square(Error) = 4,092.

*. The mean difference is significant at the ,05 level.

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Department: FRUIT GROWING

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