Effect of storage on the physicochemical and nutritional properties of blueberry (*Vaccinium corymbosum* L.) jam

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Abbreviations

FRAP: ferric reducing antioxidant power, DPPH: 2,2-diphenyl-1-picrylhydrazyl, TPC: total phenolic content, S.D.: standard deviation, ANOVA: analysis of variance.

Abstract

This study investigated the effects of storage on the physicochemical and nutritional aspects of blueberry jam. Jams were stored at either 4, 25, or 35 ºC during a 56-day period. The pH was significantly reduced during storage ($p<0.05$). Overall, results demonstrated the significant effect of storage temperature and time on the color degradation and on the texture of the samples studied ($p<0.05$). The total antioxidant activity was significantly affected by temperature as the total antioxidant activity retention of samples stored at 4 ºC was significantly higher to that of the samples stored at either 25 or 35 ºC after a 56-day storage period ($p<0.05$). A strong positive correlation was found between the total phenolic content and the antioxidant activity with R^2 ranging from 0.617 to 0.716. Results obtained herein suggested that blueberry jams should be refrigerated to better retain their overall quality attributes and their antioxidant capacity.

Practical applications

Consumption of fresh blueberries may be limited because of seasonal and market availability. Thermal processing strategies have been used in the food industry since ancient times with the aim of not only making certain foods edible but delaying the inevitable deterioration of perishable foods between production and consumption. Blueberries and other berries can be available all year round in the form of jam. The current study evaluated the effect of storage time and temperature on the physicochemical and nutritional properties of blueberry jam. Results will add current knowledge to the blueberry jam industry and facilitate the production of healthier blueberry jam.

Keywords: blueberry jam, thermal processing, storage temperature, antioxidant activity, jam making, *Vaccinium corymbosum* L.

1. Introduction

Blueberries (*Vaccinium corymbosum* L.) are sweet, nutritious, and widely popular fruits often labelled as superfoods because of their low calorie and high nutrient content. Blueberries are rich in multiple antioxidants (Morita et al., 2017) and other phytochemicals with biological properties such as anti-oxidant, anti-cancer, anti-neurodegenerative, and anti-inflammatory activities (Seeram et al., 2006). Indeed, previous studies carried out using high-fat fed rats suggested a potential anti-inflammatory effect of blueberry supplementation associated with improved glucose tolerance (Seeram et al., 2006).

Consumption of fresh blueberries may be limited because of seasonal and market availability. Thermal processing strategies have been used in the food industry since ancient times with the aim of not only making certain foods edible but delaying the inevitable deterioration of perishable foods between production and consumption. Blueberries and other berries can be available all year round in other forms such as nectar, juice, canned, or jammed. This is achieved by the destruction of microbial pathogens and the reduction of spoilage microorganisms as well as the inactivation of enzymes involved in food deterioration. Jam making is one of the most popular fruit preservation methods which can not only prolong the acceptability of fruits but also increase the availability of any selected fruit during off-season (Rababah et al., 2011a). Jams are semi-solid gel-like consistency food products that results from the cooking of the mixture of one or many fruits, sugar, and water to achieve a concentration of total soluble solids higher than 68% (Fügel et al., 2005). Other additives such as pectin or organic acids including citric or acetic acid are generally used in jam formulations. Jam quality deteriorates from the time it was produced until it is consumed (Ferreira et al., 2004). Previous studies suggested that quality and shelf-life of jams depend on factors including processing (Poiana et al., 2012), cultivar (Wicklund et al., 2005), or storage time and temperature (Touati et al., 2014). For example, Touati et al. (2014) recently reported that the interaction time-temperature had a significant effect on pH, total sugar and free amino acid content, and the sensorial profile of apricot (*Prunus armeniaca*) jam during a 60-day storage period. Furthermore, Patras et al. (2011) observed a decrease in the antioxidant activity of strawberry jam after a 28-day storage period at either 4 or 15 ^{0} C. In that study, results showed a higher stability of nutritional parameters at 4 ^{0} C when compared to 15 ^{0} C.

The aim of this study was to assess the effects of different storage conditions during a 56-day period on the physicochemical and nutritional properties of blueberry jam. Physicochemical aspects studied included pH, color, and texture while the main nutritional aspects evaluated were the total phenolic content (TPC) and the antioxidant activity measured using the ferric reducing antioxidant power (FRAP) and the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity assays.

2. Materials and methods

2.1 Chemicals and reagents

Methanol, DPPH, sodium carbonate, Folin-Ciocalteu's reagent, gallic acid, sodium acetate, acetic acid, metaphosphoric acid, 2,4,6-Tris(2-pyridyl)-s-triazine, and ferric chloride were purchased from Sigma-Aldrich (Steinheim, Germany). All reagents used were of analytical grade. Blueberries, lemons, and sugar used for jam making were purchased from local supermarkets.

2.2 Homemade jam preparation and storage

Blueberry jams were prepared following a traditional recipe. Briefly, blueberries were washed thoroughly upon reception and each lot was divided into two equal parts: one was mashed and the other one was left untreated. The juice of one lemon and sugar at a blueberry to sugar ratio of 100:75 (w/w) were added to the blueberries and the mixture was processed at 95 ^{0} C during 20 min. After processing, 50 g of jam were poured into sterilized 60 g glass bottles, left cool at room temperature, and sealed.

Jams were stored at either 4, 25, or 35 ^{0} C during a 56-day period and were analyzed at days 0, 7, 14, 21, 28, and 56.

2.3 Color measurement

Color recordings were taken using a Minolta CR-200 colorimeter (Minolta INC, Tokyo, Japan). CIE values were recorded in terms of L* (lightness), a* (redness/greenness), and b* (yellowness/blueness). Calibration was carried out using a standard white tile (Y:92.5, x:0.3161, y:0.3321) provided by the manufacturer and the D65 illuminant, which approximates to daylight.

2.4 Texture

Firmness was tested using a TA.XT-Plus Texture Analyser (Stable Micro Systems, Surrey, UK) following the methodology described by Rababah et al. (2011a).

2.5 Determination of the total phenolic content

TPC was determined using the Folin-Ciocalteu's reagent following the method described by Patras et al. (2011). Values measured at day 0 were used to calculate the decrease in TPC, expressed as percentage decrease.

2.6 Assessment of antioxidant activity

Antioxidant activity was measured using two different methods: the FRAP and the DPPH radical scavenging activity assay. The FRAP assay was carried out following the methodology described by Wicklund et al. (2005). In addition, the DPPH radical scavenging activity assay was carried out following the methodology previously reported by Rababah et al. (2011a). Values measured at day 0 were used to calculate the decrease in antioxidant activity, expressed as percentage decrease.

2.7 Statistical analysis

All tests were replicated three times. Results are expressed as mean ± standard deviation (S.D.). Difference between samples were analyzed using analysis of variance (ANOVA) with JMP 13 (SAS Institute Inc., Cary, USA). Where significant differences were present, a Tukey pairwise comparison of the means was conducted to identify where the sample differences occurred. The criterion for statistical significance was $p<0.05$.

3. Results and discussion

3.1 Physicochemical parameters

Prior to storage, the pH of the samples was 2.9 ± 0.0, higher when compared to other jams such as apricot (Touati et al., 2014), strawberry (*Fragaria ananassa*) (Rababah et al., 2011b), or umbu-caja (*Spondias tuberosa*) (de Oliveira et al., 2015). The decrease in pH was significant during storage ($p<0.05$). Figure 1 shows the effects of storage time and temperature on the pH. Overall, no differences were observed between the pH of the different samples during the first 28 days of storage. However, after a prolonged storage period at either 4, 25, or 35 ºC the pH decreased from 2.94 ± 0.0 to 2.48 ± 0.01, 2.40 ± 0.00, and 2.40 ± 0.00 respectively. The decrease in the pH was higher after storage at 25 and 35 ºC when compared to refrigerated storage at 4 ºC ($p<0.05$).

One of the most important parameters to which consumers are sensitive when selecting foods is color. Table 1 lists the color attributes of blueberry jams during a 56-day storage period. No differences were observed between the L^* and b^* values of jams stored at 4, 25, or 35 ºC after 56 days of storage. However, Table 1 indicates that storage significantly affected the color of the jams. The L^*value of jams stored at 4, 25, and 35 ºC was slightly higher after a 56-day storage period ($p<0.05$). Results contrast with previous studies which observed a decrease in L^* values after a 28 days of storage at 15 ºC (Patras et al., 2011). The opposite trend was observed for the a^* and b^* values where a significant decrease was observed during storage ($p<0.05$). The color intensity (chroma) was also significantly reduced after storage from 1.2 ± 0.0 measured at day 0 to 1.1 ± 0.0, 1.0 ± 0.0, and 0.9 ± 0.0 after storage at 4, 25, or 35 ºC, respectively ($p<0.05$). Similar results were observed previously in strawberry jams (Patras et al., 2011). Table 1 also shows the gelling strength of the samples during storage. No significant differences were observed between the firmness of samples stored at 25 ºC at day 0 and after 56 days of storage. However, during storage, the increase in firmness was significant for those samples stored at 4 and 35ºC ($p<0.05$). Storage also resulted in increased hardness in jam samples previously (de Oliveira et al., 2015). Rababah et al. (2011a) showed no variations on firmness of strawberry jams during a 15-day storage period at 45 ºC.

Overall, results demonstrate the significant effect of storage temperature and time on the color degradation and on the texture of the samples studied. New studies are needed for sensory assessment during the storage of blueberry jam to evaluate the impact of increased hardness on the sensory traits of the samples. Color differences could be caused by the degradation of colored phytochemicals including anthocyanins that occurs during thermal processing and storage. Indeed, Poiana et al. (2012) observed losses ranging between 81 and 84% in the total anthocyanin content of bilberry (*Vaccinium myrtillus*) jams during thermal processing. Similar results were obtained by Šavikin et al. (2009) in black currant (*Ribes nigrum*) and black raspberry (*Rubus occidentalis*) jams.

3.2 Nutritional properties: Total phenolic content and antioxidant activity

Several research groups have suggested the importance of fruit phenolics as dietary antioxidants. Compared to other fruits, berries including blueberries contain a high antioxidant capacity, generally attributed to their high concentration of phenolics such as anthocyanins (Moyer et al., 2002; Skrede et al., 2000). Figure 2 shows the effect of storage time and temperature on the TPC of blueberry jams. Overall, there was a constant decrease all throughout the storage time of the jams. Although no differences were observed between the TPC of blueberry jams stored at either 4 or 25 ºC at days 7 and 14, the TPC of the samples stored at 35 ºC was significantly lower when compared to the initial TPC ($p<0.05$). Samples stored at 4, 25, or 35 ºC during 56 days showed a decrease in the initial TPC of 40.9 ± 1.6, 32.5 ± 0.7, and 25.4 ± 1.7%, respectively. The observed decrease was significantly higher in samples stored at 4 ºC when compared to samples stored at either 25 or 35 ºC ($p<0.05$). Results suggested that the lower the storage temperature, the higher the TPC loss. Results contrast with those obtained by Howard et al. (2010) who reported that blueberry jams stored at 4 ºC retained higher levels of phenolic compounds including anthocyanins. In that study, a significant degradation of anthocyanins was observed during storage. Similar results were obtained by Patras et al. (2011) who suggested that during processing the cell structures are disrupted becoming more prone to non-enzymatic oxidation, one of the main reasons for TPC loss. Therefore, the observed reduction in the TPC during jam processing could be caused by a decrease in total anthocyanins, the main polyphenols in blueberries (Rodriguez-Mateos et al., 2014) or to disruptions in the cell structure during blueberry processing (Patras et al., 2011).

The antioxidant activity was determined using both the FRAP and the DPPH radical scavenging activity method and results are shown in Figure 3. Overall, results obtained using the FRAP method suggested a constant decrease in the total antioxidant activity. The observed decrease was significantly affected by temperature as the total antioxidant activity retention of samples stored at 4 ºC was higher to that of the samples stored at either 25 or 35 ºC after a 56-day storage period ($p<0.05$). The loss in antioxidant activity assessed using the FRAP method was higher on samples stored at 35 ºC when compared to those stored at 25 ºC during 56 days ($p<0.05$). Results obtained using the DPPH radical scavenging activity were consistent with those obtained using the FRAP method. However, no differences were observed between the antioxidant activity of samples stored at 4 and 25 ºC at day 56. Overall, results demonstrated that the antioxidant activity of blueberry jams was significantly affected by storage temperature and duration. Similar results were observed by Patras et al. (2011) who observed a 78.6 and 77.5% decrease in the antioxidant capacity of strawberry jam after a 28-day storage period at 4 and 15ºC respectively. Amakura et al. (2000) reported a decrease on the antioxidant activity of black currant, blackberry, raspberry, red currant, and strawberry jam by 50 to 60% of its initial value. The antioxidant capacity is most significantly correlated with the contents of total phenolics and anthocyanins (Poiana et al., 2012). In the current study, a strong positive correlation was found between TPC and antioxidant activity with R^2=0.617 and R^2= 0.716 for FRAP and DPPH, respectively. Similar results were found in strawberry jam (Patras et al., 2011) and in orange (*Citrus sinensis*), cherry (*Prunus avium*), and fig (*Ficus carica*) jams previously (Rababah et al., 2011b).

4. Conclusions

Berries and their derived products have often been proposed to possess health-promoting properties. However, storage and processing can affect the nutritional content of these products as well as their quality and overall acceptance. Therefore, the effects of storage conditions on the quality attributes and on the nutritional properties of blueberry jams should be considered prior to selection of storage conditions. Results obtained herein suggested that blueberry jams should be refrigerated to better retain their overall quality attributes and their antioxidant capacity. Further studies on the effect of storage time and temperature on specific phytochemicals such as anthocyanins are needed.

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Table 1. Colour and texture of blueberry jam during storage at either 4, 25, or 35 ºC

Time (days)	*L**	*a**	*b**	C	Hue	Firmness (N)
4 ºC						
0	25,02 ± 0,00 ^{Aa}	1,25 ± 0,00 ^{Ac}	0,17 ± 0,00 ^{Ac}	1,26 ± 0,00 ^{Ac}	7,74 ± 0,00 ^{Ab}	0,22 ± 0,00 ^{Aa}
7	25,78 ± 0,01 ^{Bc}	0,85 ± 0,16 ^{Ab}	0,07 ± 0,01 ^{Ab}	0,85 ± 0,16 ^{Aa}	5,08 ± 0,32 ^{Aa}	0,53 ± 0,06 ^{Bd}
14	25,83 ± 0,06 ^{Ac}	1,02 ± 0,09 ^{Bb}	0,04 ± 0,04 ^{Cb}	1,02 ± 0,09 ^{Aab}	2,64 ± 2,12 ^{Aa}	0,40 ± 0,04 ^{Bc}
21	26,85 ± 0,04 ^{Bd}	0,99 ± 0,02 ^{Bb}	-0,48 ± 0,04 ^{Aa}	1,10 ± 0,00 ^{Ab}	154,00 ± 1,50 ^{Bd}	0,56 ± 0,00 ^{Cd}
28	25,27 ± 0,13 ^{Bb}	0,01 ± 0,03 ^{Aa}	-0,53 ± 0,23 ^{Aa}	1,06 ± 0,13 ^{Aab}	82,73 ± 60,39 ^{Ac}	0,26 ± 0,00 ^{Bb}
56	25,33 ± 0,10 ^{Ab}	0,99 ± 0,04 ^{Bb}	-0,52 ± 0,08 ^{Aa}	1,11 ± 0,08 ^{Bab}	152,38 ± 2,01 ^{Bd}	0,44 ± 0,04 ^{Cc}
25 ºC						
0	25,02 ± 0,00 ^{Aa}	1,25 ± 0,00 ^{Ad}	0,17 ± 0,00 ^{Ad}	1,26 ± 0,00 ^{Ac}	7,74 ± 0,00 ^{Aa}	0,22 ± 0,00 ^{Ab}
7	25,27 ± 0,55 ^{Ab}	0,96 ± 0,12 ^{Abc}	-0,06 ± 0,18 ^{Ac}	0,97 ± 0,11 ^{Aab}	85,81 ± 82,00 ^{Bbc}	0,19 ± 0,01 ^{Aa}
14	26,10 ± 0,07 ^{Bc}	0,82 ± 0,05 ^{Abc}	-0,34 ± 0,05 ^{Bb}	0,89 ± 0,03 ^{Aa}	157,24 ± 2,93 ^{Bc}	0,25 ± 0,08 ^{ABabc}
21	26,85 ± 0,04 ^{Bc}	0,99 ± 0,02 ^{Bc}	-0,48 ± 0,04 ^{Aa}	1,10 ± 0,00 ^{Ab}	154,00 ± 1,50 ^{Bc}	0,33 ± 0,02 ^{Bc}
28	25,27 ± 0,13 ^{Bb}	0,01 ± 0,02 ^{Aa}	-0,53 ± ± 0,22 ^{Aa}	1,06 ± 0,13 ^{Aab}	82,73 ± 60,39 ^{Ab}	0,17 ± 0,07 ^{Aab}
56	25,34 ± 0,03 ^{Ab}	0,73 ± 0,08 ^{Ab}	-0,75 ± 0,18 ^{Aa}	1,05 ± 0,07 ^{ABab}	134,57 ± 7,30 ^{Abc}	0,19 ± 0,02 ^{Aab}
35 ºC						
0	25,02 ± 0,00 ^{Ab}	1,25 ± 0,00 ^{Ac}	0,17 ± 0,00 ^{Ac}	1,26 ± 0,00 ^{Abc}	7,74 ± 0,00 ^{Aa}	0,22 ± 0,00 ^{Ab}
7	24,92 ± 0,13 ^{Ab}	1,44 ± 0,26 ^{Bc}	0,16 ± 0,01 ^{Bc}	1,44 ± 0,26 ^{Bc}	6,51 ± 1,23 ^{Aa}	0,17 ± 0,03 ^{Aa}
14	26,63 ± 0,04 ^{Cd}	0,89 ± 0,13 ^{Ab}	-0,55 ± 0,00 ^{Ab}	1,04 ± 0,11 ^{Aab}	148,09 ± 2,60 ^{Bbc}	0,14 ± 0,04 ^{Aa}
21	25,05 ± 0,33 ^{Ab}	0,88 ± 0,01 ^{Ab}	-0,26 ± 0,47 ^{Ab}	0,96 ± 0,12 ^{Aa}	74,97 ± 70,43 ^{Ab}	0,17 ± 0,07 ^{Aab}
28	24,82 ± 0,11 ^{Aa}	0,79 ± 0,05 ^{Ba}	-0,43 ± 0,13 ^{Ab}	0,89 ± 0,11 ^{Aa}	151,36 ± 4,25 ^{Bc}	0,26 ± 0,03 ^{ABb}
56	25,56 ± 0,48 ^{Ac}	0,74 ± 0,03 ^{Aa}	-0,63 ± 0,04 ^{Aa}	0,97 ± 0,00 ^{Aa}	139,36 ± 1,88 ^{Ab}	0,34 ± 0,02 ^{Bc}

Different capital letters indicate significant differences between samples stored at different temperatures and different lower case letters indicate significant differences between values measured at different sampling points. The criterion for statistical significance was $p<0.05$.

Figure captions

Figure 1. Effect of storage time and temperature on the pH of blueberry jams

Figure 2. Total phenolic content retention of blueberry jams during storage at different temperatures

Figure 3. Retention of the antioxidant activity assessed using the (A) FRAP and (B) DPPH· assays

Figure 1

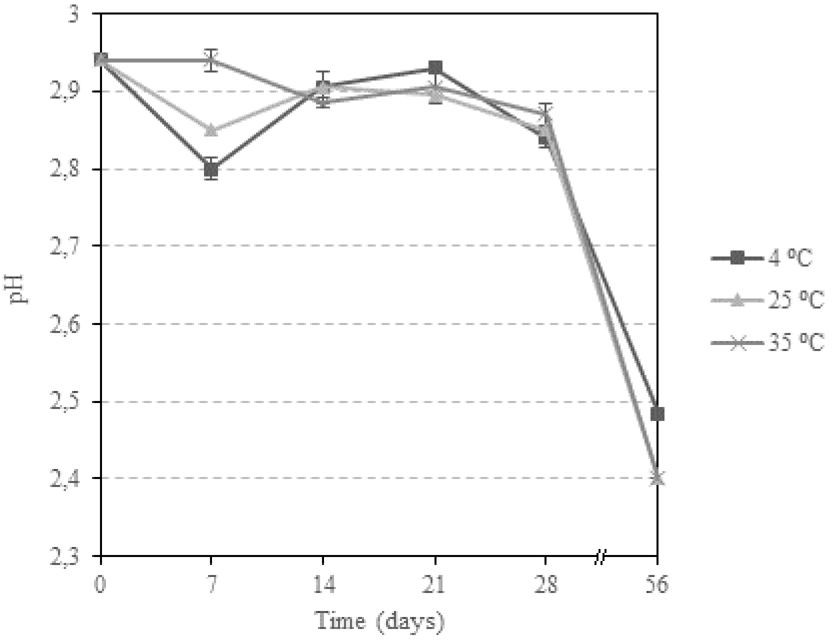


Figure 2

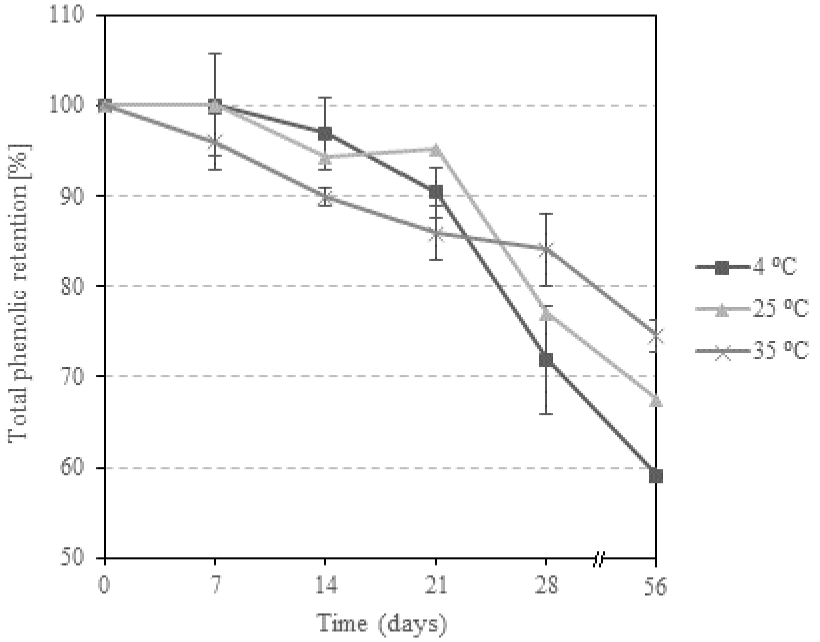
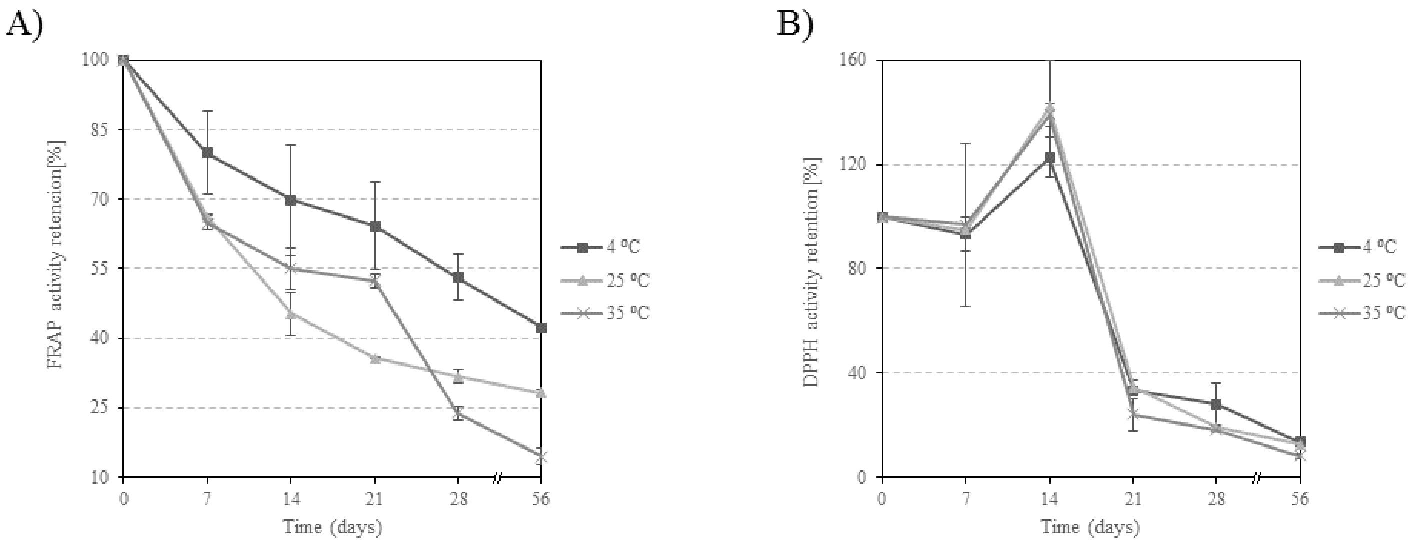


Figure 3


A)
FRAP activity retencion[%]
100
85
70
55
40
25
10
0
7
14
21
28
56
Time (days)
4 ºC
25 ºC
35 ºC
B)
DPPH activity retention[%]
160
120
80
40
0
0
7
14
21
28
56
Time (days)
4 ºC
25 ºC
35 ºC

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