



RESEARCH ARTICLE

Determination of Storage Possibilities at Different Temperatures of Badalan (A Type of Kidney Bean) Grown in Çanakkale

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ABSTRACT

Beans (*Phaseolus vulgaris* L.) have been important in human nutrition since ancient times thanks to their protein content. Badalan beans, a type kidney bean, grown in Çanakkale and the surrounding area, are also known as fresh dry or milk beans. They are stored at low temperatures (-16°C, -18°C) until they are consumed, without being dried. The storage method, which allows the product to be stored at higher temperatures and for longer periods than usual, is considered an alternative to the widespread use of the bean type. It will provide the opportunity to evaluate various alternatives such as energy saving and the effective use of deep freezer volume. In our study, Badalan beans were stored under consumer conditions at different temperatures (At temperature ranges of -18/-16°C, -10/-5°C, -4/0°C and 0/+4°C) and storage periods (3, 6, 9 and 12 months and the control (-18/-16°C-12 months)), and the storage performance of the product was evaluated in terms of parameters such as seed coat color (L*), endosperm color in seed (L*), weight loss (g), moisture content (%), sugar content (g 100 g⁻¹) and dry matter (%) ratio. The obtained results showed that Badalan beans can be stored without damage for 6 months at -10/-5°C and 12 months at -18/-16°C. To save energy and make effective refrigerator volume usage during storage, suitable storage applications are -4/0°C for three months and 0/+4°C for one month are suitable for short-term storage.

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1. Introduction

Evidence from 5000 years ago shows that legumes were used for nutritional purposes by the Mediterranean, Egyptians, Mesopotamians, Trojans, Hungarians, and British peoples (Pekşen & Artık, 2005). Beans, which belong to the legume family, were produced in Türkiye in 2023 at a rate of 240,000 tonnes (TÜİK, 2025) and have become an essential source of protein, particularly for vegans and vegetarians who do not consume animal products. Bean seeds are also known to contain as lysine, valine, glutamic acid and methionine like amino acids, and phaseolin is a key amino acid in bean protein

(Montoya et al., 2008, 2010). However, while animal-based proteins are important sources of protein, factors such as cost, rapid spoilage and differing attitudes towards meat consumption mean that plant-based proteins, which are easily produced, stored and obtained at an affordable cost, are important alternatives (Sözen et al., 2022).

Beans, which have a very rich genetic diversity and are grown across a wide range of geographies areas. Varieties differ in characteristics such as color, pod size, and tissue structures depending on country or region due to consumers' different consumption preferences (Orzolek et al., 2000). Badalan beans,

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which are grown in Çanakkale and surroundings areas and are known by various names (milk beans, fresh dry, etc.), are sold for a short time due to the way they are consumed which leads consumers to store them at home. However, studies have generally focused on fresh beans. Cantwell and Suslow (2010) stated that fresh beans are susceptible to low temperatures and have a higher respiration rate than other stored products. They also suggested storing them for 8-12 days at 5-7.5°C and 95% relative humidity, as they spoil quickly. Beans are known to be stored in cold storage for short periods to balance long-term transportation and supply/price (Koyuncu, 2017). Beans are mainly stored by drying. However, the storage performance of Badalan is undetermined as it does not have thoroughly dried bean grains.

This study aims to investigate the storage possibilities of Badalan beans, which have a unique consumption style, at different temperatures and for different durations and to use the obtained data to provide new alternatives for storing the product. In this sense, the study aims to contribute to energy saving and the effective use of deep freezer volume, as well as

increasing demand for the product by ensuring consumers demands more of it.

2. Materials and Methods

2.1. Materials

In the study, kidney beans, which were grown in Çanakkale, were used as plant material and are called fresh dry, milk beans or Badalan in local markets. Kidney beans, among the types of beans, are products that can be consumed in different ways, such as fresh pods, immature seeded pods, and dry seeds. Badalan beans, which are intensively cultivated in the entire province, especially in the central districts and villages of Çanakkale and in surrounding provinces such as Balıkesir, are harvested during the maturity period, that is, when the pods that have reached the harvest period have to bead, the seeds have enlarged and become visible from the outside. The pods have dried moderately and turned yellow-brown, and they can be easily opened from their middle seams, and the seeds can be separated from the fruit.



Figure 1. Harvested pods of badalan beans, sorted grains (a), and packaging application before storage (b).

2.2. Methods

The average thousand seed weight of the beans was determined as 647.76 g. They were separated from the pods, cleaned, and packed in refrigerator bags (consumer conditions). They were stored at storage the control (-18/-16°C-12 months) and three different temperature levels (at temperature ranges of -18/-16°C, -10/-5°C, -4/0°C and 0/+4°C) for 3, 6, 9, and 12 months. The experiment was planned according to the randomized plots trial design with three replicates and 500 g of seed in each replicate. The criteria examined in the experiment were

Testa L* value: The brightness value on the testa was measured as L* with a Minolta CR-3000 colorimeter on 30 seeds in each application replication.

Endosperm L* value: The brightness value on the endosperms was measured as L* with a Minolta CR-3000 colorimeter on 30 seeds split in half in each application and replication.

Weight loss (%): This was found by dividing the initial storage weight by the weight after storage for each replication.

Moisture ratio (%): Seed moisture was kept in a 105°C oven for 17 hours using the ISTA (1993) rules and calculated as % using Equation 1.

$$\text{SMC (\%)} = \frac{\text{fresh weight} - \text{dry weight}}{\text{fresh weight}} 100 \quad (1)$$

Where, SMC is seed moisture content.

Total sugar amount (g 100 g⁻¹): The dinitrophenol method specified by Ross (1959) was used to determine the total sugar amount.

Dry matter (%): The values obtained from the readings on the Near Infrared Reflectance (NIR) device were expressed as a percentage by comparing them.

Statistical analyses in the experiment were performed using the SPSS (ver.21) package program. In this context, variance analysis and Tukey (5%) multiple comparison tests were applied.

3. Results and Discussion

3.1. Testa and Endosperm L* Value

The effects of storage periods and temperatures on the shell color are given in Figure 2 and Table 1. While storage period

was found to be statistically insignificant in the color change of the seed coat, temperature treatments and the interaction of temperature treatments x storage periods (temperature x period) were found to be statistically significant at 1%.

Table 1. Testa brightness values (L*).

Temp. (°C)	Storage Times				
	3 Months	6 Months	9 Months	12 Months	Average Temp.
-18/-16	69.66 Aa	69.28 Aa	69.09 Aa	68.88 Ba	69.23 a
-10/-5	61.36 Cd	65.53 Bc	67.62 Bb	72.83 Aa	66.84 a
-4/0	55.94 Da	54.87 Ca	47.68 Cb	41.02 Cc	49.88 b
0/+4	67.67 Bb	66.48 Bc	69.00 Aa	68.00 Bab	67.79 a
Average Str T.	63.66	64.04	63.43	62.68	f=52.740**
Significance Level	N.S.				

St. Dev: 8.94. Temperature x Storage Time: f=58.512**.

*: Significant at 5% level, **: Significant at 1% level, N.S.: Not Significant.

The differences in storage temperatures indicated by different uppercase letters for each storage duration are significant.

The differences in storage durations indicated by different lowercase letters for each storage temperature are significant.

While the effects of storage periods on the shell color were similar, the lowest brightness value in storage temperatures was determined in beans stored at 0/-4°C for 12 months. It was determined that the testa brightness had similar values in

products stored at other temperatures (Figure 2b). The lowest brightness value was measured in the same application when the temperature effect was considered.

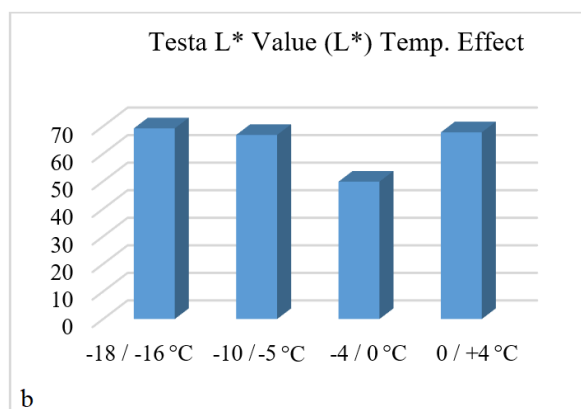
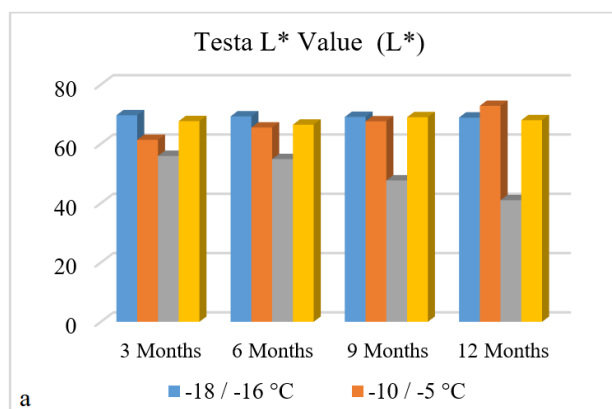


Figure 2. Testa brightness Values (L*) under the influence of different temperatures and storage times. a: Temperature x Storage time interaction, b: Storage temperature effect.

The effects of storage times and temperatures on endosperm L* values are given in Figure 3 and Table 2. As a result of the statistical analysis, the effects of storage times were found to be insignificant, while temperature treatments and temperature x time interaction were found to be statistically significant at the 1% level.

When the endosperm brightness value results were examined, the values showed a decreasing trend in beans stored for 9 and 12 months. Similar to the testa brightness values, the effects of storage temperatures also showed a decrease in endosperm color in beans stored at 0/-4°C (Figure 3b).

Table 2. Endosperm brightness values (L*).

Temp. (°C)	Storage Times				
	3 Months	6 Months	9 Months	12 Months	Average Temp.
-18/-16	66.76 Aa	66.66 Aa	62.66 Bb	65.96 Aa	65.51 a
-10/-5	58.27 Bc	59.99 Bb	59.60 Cb	65.63 Aa	60.87 b
-4/0	50.82 Cb	52.67 Ca	43.51 Dc	40.49 Cd	46.87 c
0/+4	67.66 Aa	65.77 Ab	68.33 Aa	62.49 Bc	66.06 a
Average Str T.	60.88	61.27	58.52	58.64	
Significance Level	N.S.				f= 65.498**

St. Dev: 8.69. Temperature x Storage Time: f= 39.532**.

*: Significant at 5% level, **: Significant at 1% level, N.S.: Not Significant.

The differences in storage temperatures indicated by different uppercase letters for each storage duration are significant.

The differences in storage durations indicated by different lowercase letters for each storage temperature are significant.

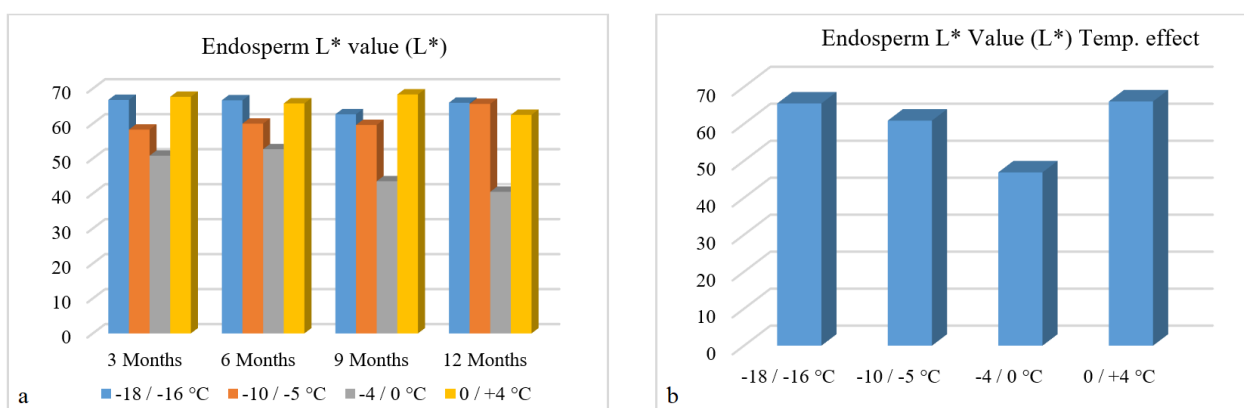


Figure 3. Endosperm brightness values (L*) under the influence of different temperatures and storage times. a: Temperature x Storage time interaction, b: Temperature effect on Endosperm Brightness value.

In Badalan bean, seed coat color and endosperm color showed similar trends. Both parameters were significantly affected by storage temperatures, and beans stored at 0°C/-4°C were found to have the lowest brightness values. In a study conducted by Rani et al. (2013), the initial L* value of the Pinto bean seed coat was 93.1. Still, it was determined that there was a significant decrease in the L* value with the increase in storage temperature and duration. Although similar decreases were observed in our study, this decrease was greatest in beans stored at 0°C/-4°C. The same researchers mentioned that seed coat color is essential for the visual quality and market value of legume products, especially beans. The storage environment plays a vital role in accelerating postharvest darkening of beans. In their research, Kibar and Kibar (2019) found that beans with different moisture contents were stored for 12 months, and the resulting L* values were between 47, 42 and 70, 72, parallel to the results obtained in our study.

3.2. Weight Loss (g)

The results obtained in the study in terms of weight loss due to water loss in stored fruits and vegetables are presented in Figure 4. Compared to other applications, the 12-month application at +4/0°C, which has the longest storage period and the highest storage temperature, experienced the highest weight loss with an average of 6.79%, while the 3-month application at -16/-18°C was found to be the application with the lowest weight loss with an average of 0.98%. As a predictable result, while the weight loss is low as the storage temperature decreases and in short-term storage periods, the losses increase with increasing temperature and long-term storage periods.

Jany et al. (2008) reported in their study with various vegetables that the weight loss in beans stored at 4°C for 9 days increased to 3%, while in samples stored at -18°C for 90 days, the weight loss reached 2.5%. The weight loss trend revealed in the researchers' study indicates results similar to this study's.

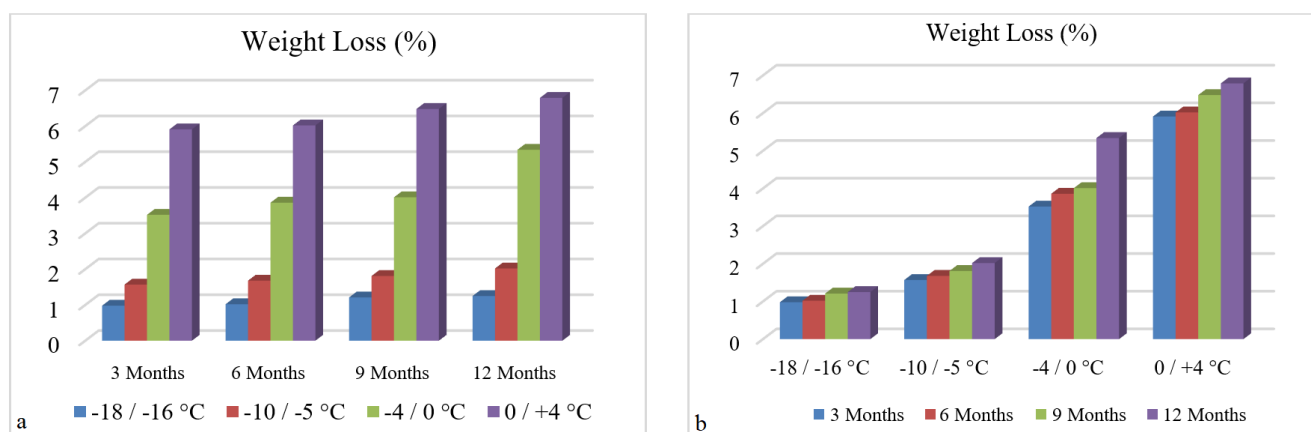


Figure 4. Effect of different temperatures and storage times on weight loss in the product (%). a: Effect of temperature on weight loss, b: Effect of storage time on weight loss.

3.3. Seed Moisture Content (%)

The moisture contents of Badalan bean seeds at different temperatures and storage periods are summarized in Figure 5 and Table 3. When the application effect on the moisture

content was evaluated, the storage period effect was found to be insignificant, while the temperature effect (Figure 5b) and the temperature x time (Figure 5b) interaction were found to be statistically significant at 1%.

Table 3. Seed moisture (%).

Temp. (°C)	Storage Times				Average Temp.
	3 Months	6 Months	9 Months	12 Months	
-18/-16	49.52 Bb	51.69 Ba	49.37 Cb	47.49c	49.52 b
-10/-5	53.08 Aa	45.02 Cc	51.01 Bb	49.69b	49.70 b
-4/0	40.82 Ca	38.12 Db	32.94 Dc	30.02d	35.47 c
0/+4	54.07 Ac	55.90 Aab	56.77 Aa	54.91bc	55.41 a
Average Str T.	49.37	47.68	47.52	45.53	
Significance Level	N.S.				f= 71.874**

St. Dev: 8.221 Temperature x Storage Time: f= 28.261**.

*: Significant at 5% level, **: Significant at 1% level, N.S.: Not Significant.

The differences in storage temperatures indicated by different uppercase letters for each storage duration are significant.

The differences in storage durations indicated by different lowercase letters for each storage temperature are significant.

The moisture contents of the samples took close values in terms of storage periods. When the results obtained regarding storage process temperatures were evaluated (Figure 5b), the highest moisture content was found in beans stored at 0/+4°C. The beans with the lowest moisture content were obtained from -4/0°C temperature applications. The moisture value in the beans tended to decrease, though irregularly, with the decrease in temperature. In the samples in our study, the moisture values

varied between 30.02% and 56.77%. The reasons for this remarkable moisture loss occurring at different temperatures are the natural moisture loss occurring above 0°C and the tissues hardening due to the freezing effect at temperatures below 0°C and the low temperature preventing evaporation. Based on this, it is possible to say that storage temperatures are particularly effective on seed moisture content values.

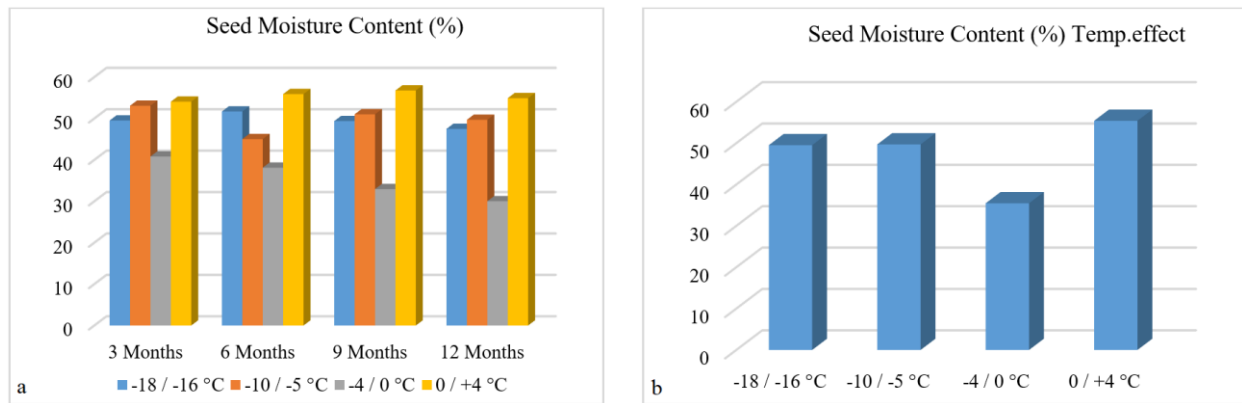


Figure 5. Seed moisture (%) rates under the influence of different temperatures and storage times. a: Temperature x Storage time interaction, b: Effect of seed moisture storage temperature.

Wani et al. (2010) reported that the grain moisture value varied between 12.1% and 14.5% in a study on four different types of kidney beans. Wu et al. (2015) stored kidney beans at different temperatures and durations. In the samples stored at 7.1°C, the moisture content increased as the storage period extended, and in the samples stored at -20°C, it followed a fluctuating course similar to the values in our study. However, the moisture values obtained in other researchers' studies are quite low compared to the values in our study. This situation is directly due to the consumption characteristics of badalan beans, in other words, not being included in the drying process at the point of storage and their high moisture content. The beans, called badalan, are consumed without being completely dried or stored at low temperatures until frozen. Accordingly,

they contain higher moisture compared to beans consumed as dried grains.

3.4. Sugar Content (g/100g)

The effects of the applications on the amount of reduced sugar during the research process are presented in Figure 6 and Table 4. While the effects of temperature and storage time were statistically insignificant on their own, the temperature x time interaction was significant at the 1% level, and the highest value was obtained from the 6-month storage application at 0/-4°C. In terms of storage times, the highest reducing sugar amount was observed in the 6-month storage period, while the highest value in storage temperature was obtained from the -16/-18°C storage application.

Table 4. Reducing sugar amounts (g/100g).

Temp. (°C)	Storage Times				Average Temp.
	3 Months	6 Months	9 Months	12 Months	
-18/-16	2.29 Aa	1.43 Bb	0.29 Bd	1.06 Bc	1.27
-10/-5	0.34 Cc	0.34 Cc	1.84 Aa	1.43 Ab	0.99
-4/0	0.40 Cb	2.40 Aa	0.26 Bb	0.06 Dc	0.78
0/+4	0.77 Ba	0.34 Cc	0.14 Bd	0.57 Cb	0.46
Average Str T.	0.95	1.13	0.63	0.78	
Significance Level	N.S.				N.S.

St. Dev: 0.80 Temperature x Storage Time: $f = 20.575^{**}$.

*, Significant at 5% level, **, Significant at 1% level, N.S.: Not Significant.

The differences in storage temperatures indicated by different uppercase letters for each storage duration are significant.

The differences in storage durations indicated by different lowercase letters for each storage temperature are significant.

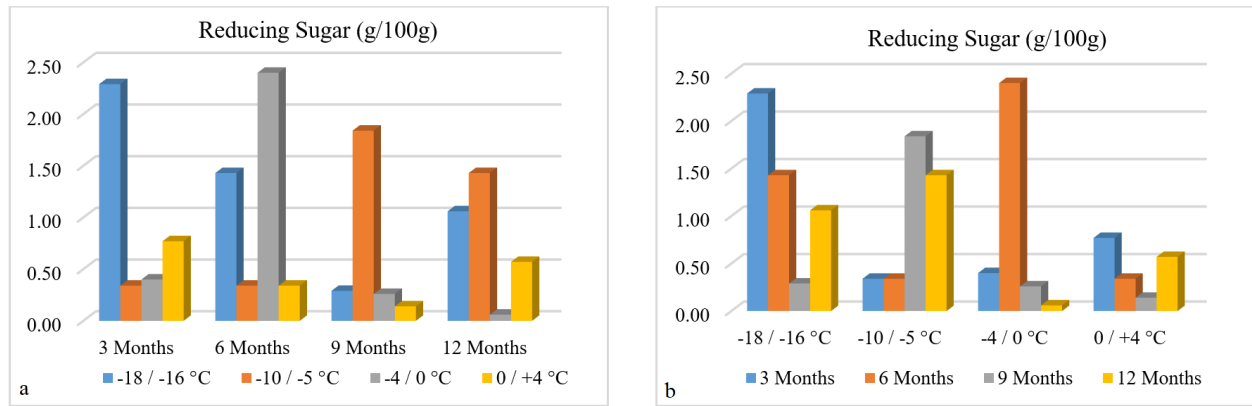


Figure 6. Reducing sugar values under the influence of different temperatures and storage times (g/100g). a: Temperature x storage time interaction (duration) b: Temperature x storage time interaction (temperature).

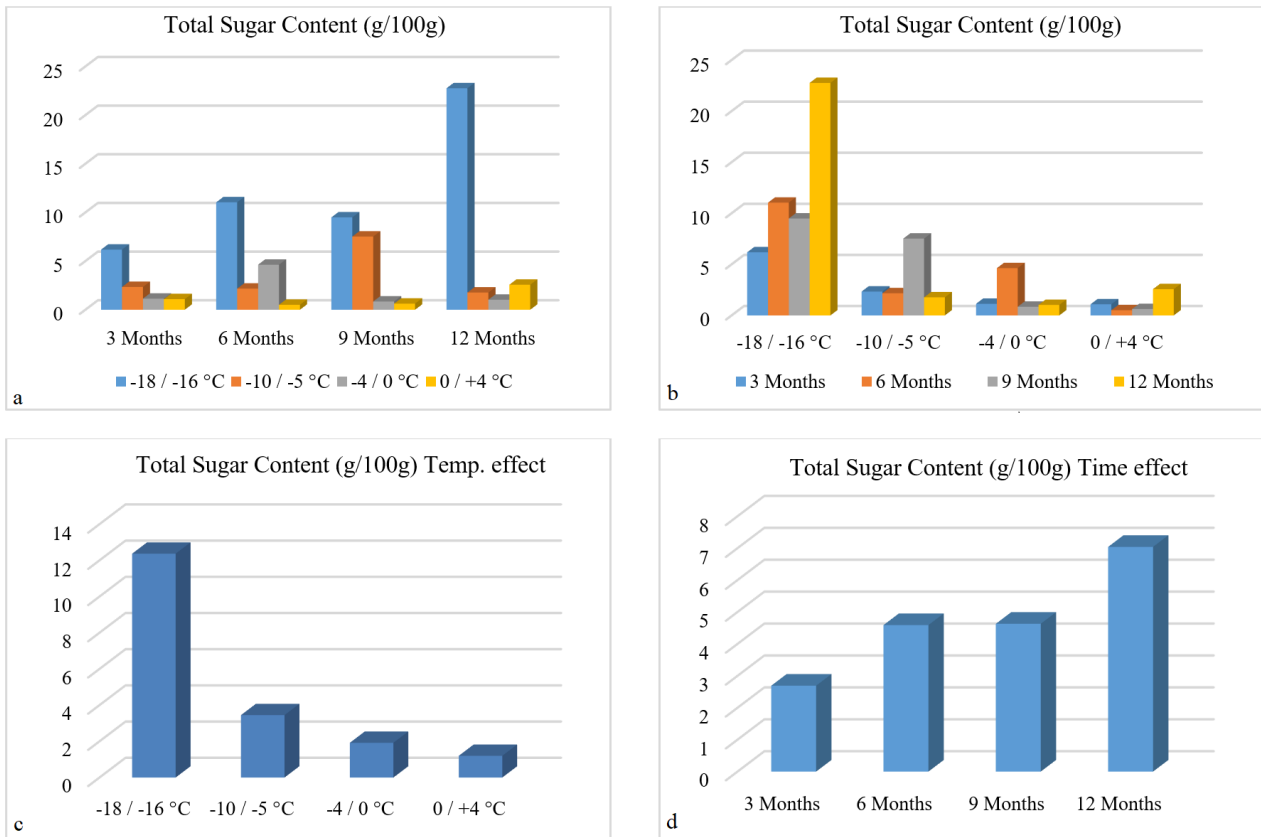


Figure 7. Total sugar values (g/100g) under the influence of different temperatures and storage times. a: Temperature x Storage time interaction, b: Temperature x Storage time interaction, c: Temperature effect on the total sugar amount, d: Storage time effect on the total sugar amount.

The effect of storage time and temperature on total sugar amount is summarized in Figure 7 and Table 5. While storage periods were statistically significant at the 5% level (Figure 7d), temperature treatments (Figure 7c) and temperature x time interaction had a significance level of 1%. In terms of storage times, the highest total sugar amount was observed in the 12-

month storage period, while in terms of storage temperature, the highest value was obtained from the -16/-18°C storage application. When the data were evaluated in terms of temperature x time interaction, the highest total sugar amount was obtained from the storage application continued at -16/-18°C for 12 months.

Table 5. Total sugar amounts (g/100g).

Temp. (°C)	Storage Times				
	3 Months	6 Months	9 Months	12 Months	Average Temp.
-18/-16	6.18 Ad	11.04 Ab	9.49 Ac	22.76 Aa	12.37 a
-10/-5	2.34 Bb	2.17 Cb	7.52 Ba	1.77 Cc	3.45 b
-4/0	1.14 Cb	4.63 Ba	0.85 Cc	1.03 Dbc	1.92 b
0/+4	1.09 Cb	0.51 Dc	0.63 Dc	2.57 Ba	1.20 b
Average Str T.	2.69 b	4.59 ab	4.63 ab	7.04 a	
Significance Level	f= 3.355*				f= 28.384**

St. Dev: 5.73 Temperature x Storage Time: f= 665.958**.

*: Significant at 5% level, **: Significant at 1% level, N.S.: Not Significant.

The differences in storage temperatures indicated by different uppercase letters for each storage duration are significant.

The differences in storage durations indicated by different lowercase letters for each storage temperature are significant.

The effects of storage periods and temperatures on sucrose content are summarized in Figure 8 and Table 6. While storage periods were statistically significant at the 5% level (Figure 8d), temperature treatments (Figure 8c) and temperature x time interaction had a significance level of 1%. In terms of storage periods, the highest sucrose content was observed in the 12-

month storage period, while the highest value in storage temperature was obtained from the -16/-18°C storage application. When the temperature x time interaction data was evaluated, the highest sucrose content was obtained from the -16/-18°C storage application that continued for 12 months.

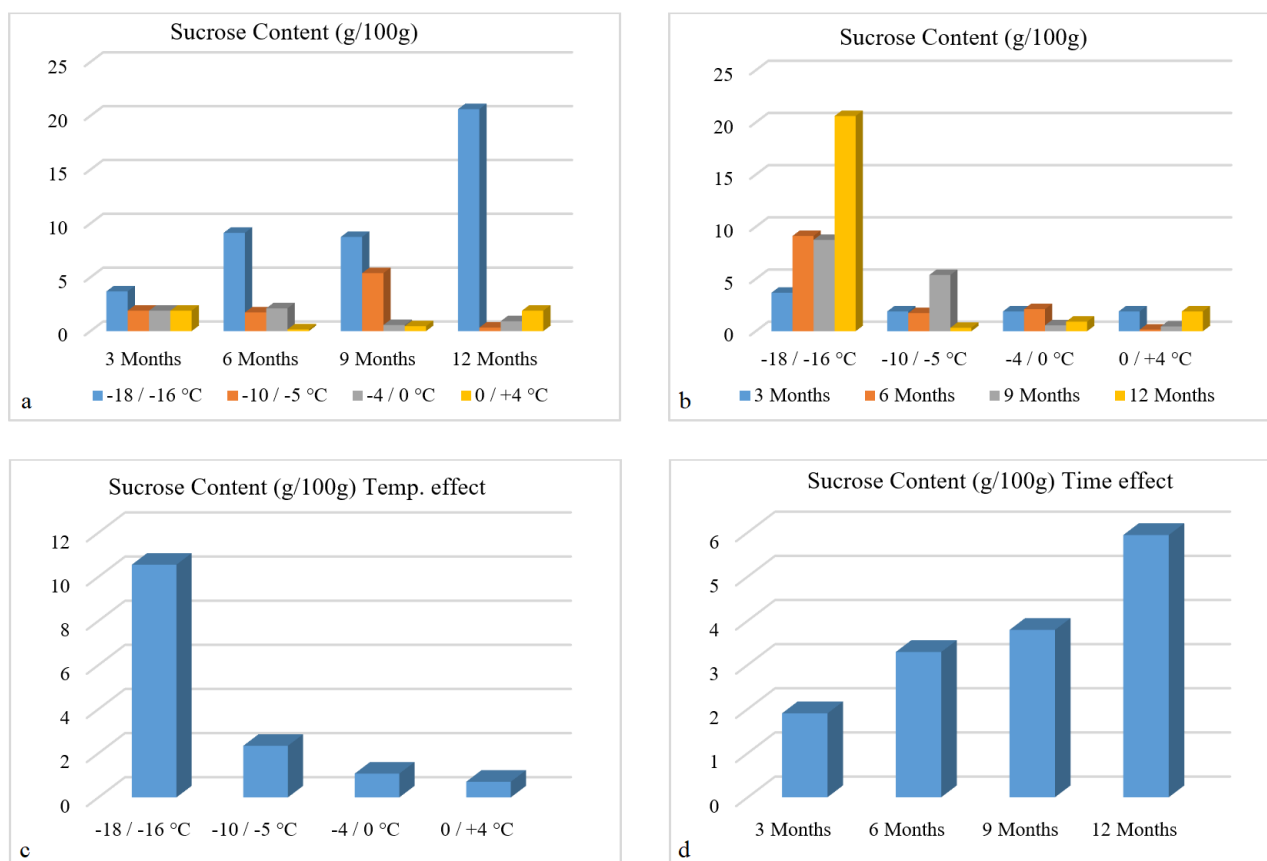


Figure 8. Sucrose values (g/100g) under the influence of different temperatures and storage times. a: Temperature x Storage time interaction, b: Temperature x Storage time interaction, c: Temperature effect on the total sugar amount, d: Storage time effect on the total sugar amount.

Legumes and bean varieties included in this group are essential food sources due to their high starch content accumulated in the endosperm tissue. The starch accumulated

in the endosperm tissue is broken down into sucrose and sugar sub-fractions through a slow metabolic activity until the point of consumption. This process plays a significant role in

enhancing the flavor of the food and its desirability for consumption.

Table 6. Sucrose contents (g/100 g).

Temp. (°C)	Storage Times				Average Temp.
	3 Months	6 Months	9 Months	12 Months	
-18/-16	3.69 Ad	9.13 Ab	8.75 Ac	20.62 Aa	10.55 a
-10/-5	1.90 Bb	1.74 Cc	5.39 Ba	0.33 Dd	2.34 b
-4/0	0.71 Cc	2.12 Ba	0.57 Cd	0.92 Cb	1.08 b
0/+4	0.30 Dc	0.16 Dd	0.46 Db	1.90 Ba	0.71 b
Average Str T.	1.65 b	3.29 ab	3.79 ab	5.94 a	f= 26.461**
Significance Level	f= 3.848*				

St. Dev: 5.23 Temperature x Storage Time: f=10312.260**.

*: Significant at 5% level, **: Significant at 1% level, N.S.: Not Significant.

The differences in storage temperatures indicated by different uppercase letters for each storage duration are significant.

The differences in storage durations indicated by different lowercase letters for each storage temperature are significant.

In our study, the highest values in reducing sugar content were achieved during a storage application at -4°C/0°C for 6 months, while the highest total sugar and sucrose amounts were obtained through a storage application at -18/-16°C for 12 months. As the storage time and temperature increase, the amount of reducing sugars generally decreases. Conversely, the total sugar and sucrose amounts show a tendency in the opposite direction. In the study conducted by Słupski and Gębczyński (2014), the sucrose content in flageolet-type beans was between 0.551-0.791 g/100g. In another study by Martins et al. (1999), bean samples were stored at -18°C for different durations. After a three-month storage period, the reducing sugar value was determined to be 0.16 g/100g, while the total

sugar amount was 1.94 g/100g. In similar applications in our study, higher sugar amounts were obtained, concluding that the diversity of the varieties may have influenced this result.

3.5. 3.5. Dry Matter Rate (%)

Changes in the dry matter content of the product under different temperature and storage time conditions were found to be statistically insignificant regarding the interaction of temperature x storage time and the effect of storage duration (Figure 9a). However, storage temperature was identified as an effective factor (Figure 9b and Table 7). The highest dry matter content was achieved with a value of 92.88% during storage applications at 0/+4°C.

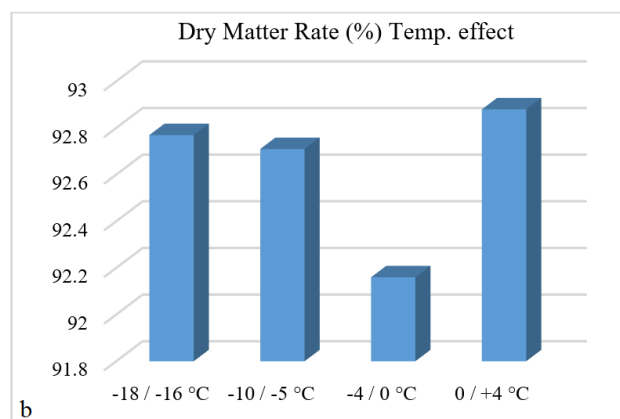
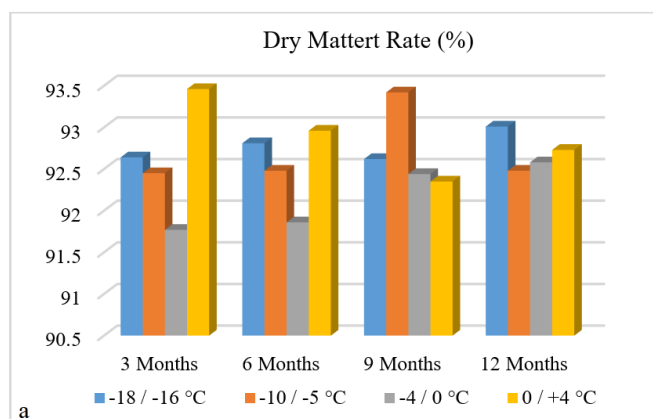


Figure 9. Dry matter ratio (%) under the influence of different temperatures and storage times. a: Temperature x Storage time interaction, b: Temperature effect on dry matter ratio.

Another critical characteristic of beans evaluated in terms of nutrition is their dry matter content. When assessing the effects of treatments on the dry matter content of the Badalan bean, the results were found to vary between 93.46-91.77 g/100g. Similarly, a study conducted by Prolla et al. (2010) determined the dry matter content of beans as 86.67-87.09

g/100g. Słupski and Gębczyński (2014), in their study where they stored beans for 12 months, concluded that the dry matter content decreased somewhat after storage. This study also noted decreases in dry matter content due to decreased storage temperatures.

Table 7. Dry matter ratio (%).

Temp. (°C)	Storage Times				
	3 Months	6 Months	9 Months	12 Months	Average Temp.
-18/-16	92.64	92.81	92.62	93.01	92.77ab
-10/-5	92.45	92.48	93.42	92.48	92.71ab
-4/0	91.77	91.86	92.44	92.58	92.16b
0/+4	93.46	92.96	92.35	92.73	92.88a
Average Str T.	92.58	92.53	92.71	92.70	
Significance Level	N.S.				f= 2.978*

St. Dev: 0.66 Temperature x Storage Time: N.S.

*: Significant at 5% level, **: Significant at 1% level, N.S.: Not Significant.

4. Conclusion

Badalan is a valuable product, especially consumed fresh by the residents of its cultivation hinterland, and is highly demanded in local markets. Consumers store it in freezer bags at -18°C/-16°C temperatures, consuming it gradually throughout the winter. This paper on this product concluded that storage conditions at -10/-5°C for 6 months and -18/-16°C for 12 months could be the ideal storage conditions for Badalan. However, if shorter storage periods are planned, storing for 3 months at -4/0°C and 1 month at 0/+4°C are also viable options. Planning a storage strategy in this direction for Badalan will provide significant benefits in terms of energy savings and volume management in the freezer. For products to be stored and consumed in a short period, higher temperature storage practices than deep freezing will allow for more effective use of freezer volume by having the option to move products to cooler areas with higher temperatures. Additionally, to shed light on new research on Badalan, also known as milk beans or fresh dry beans, investigating different packaging types during the storage process and sterilization practices before storage will significantly contribute to filling the literature gap on this subject.

Compliance with Ethical Standards

This study does not require ethical committee approval.

Acknowledgment

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Conflict of Interest

The authors declare no conflict of interest.

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