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KINETICS OF COLOR DEGRADATION DURING STORAGE OF HARD CANDIES OF DYE FROM THE GRIS FLOWER WITH ARTIFICIAL INTELLIGENCE

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ABSTRACT

The kinetics of color degradation during storage of hard candies with the addition of dye from the orange cress flower (*Tropaeolum majus L.*) was evaluated. The flowers were collected, which were conditioned to obtain the anthocyanin extract, encapsulated with 10% maltodextrin and spray-dried at 160°C. Then candies were made with anthocyanin extract and powder, which were stored at 20, 25, 30 and 35°C for 28 days, evaluating the a*, b* and L* values to determine the kinetics. The rate of degradation (K) in the candies with extract coloring (CCE) varied from 0.00368 to 0.00737 days^{-1}; decimal reduction times (D) were 625 to 313 days; the mean degradation time ($t_{0.5}$) ranged from 188 to 94 days; the temperature coefficient (Q10) was 1.517; the heat resistance capacity (Z) was 55.249°C and the Activation Energy (Ea) 7.436 Kcal/mol. For candies with powdered coloring (CCP) the value of K was from 0.00322 to 0.00691 days^{-1}; the D value from 333 to 714 days; $t_{0.5}$ from 100 to 215 days; Q10 turned out to be 1.622; the Z value was 47.619°C and finally an Ea of 8.700 Kcal/mol; The correlations of the luminance and time variables evidenced first-order kinetics for the two candy formulations. The development of AI has allowed robots to acquire the ability to learn from their mistakes, adapt to novel situations, and carry out other functions hitherto reserved for human beings. Particularly in deep learning and natural language processing, the use of AI in the real world is on the increase. Artificial intelligence encompasses more than just chess-playing computers and self-driving cars.

1.Introduction

Color is the first sensation that a food is perceived, and the one that determines the first judgment about its quality (McDonald, 2018). It is also an important factor within the set of sensations that food provides and sometimes tends to subjectively modify other sensations such as taste and smell (Cai and chi, 2020). It is possible, for example, to confuse a panel of tasters by coloring products such as ice cream with a color that does not correspond to that of the aroma used (Gallace et al., 2011).

Natural foods have their own color, so at first it would seem ideal to maintain them throughout the transformation process (Bibi et al., 2020). However, consumers prefer a constant color in certain foods, which does not vary between the different manufacturing batches of a product (Tijskens and Schouten, 2022). The natural variability of raw materials means that this normalized color can only be obtained by artificially modifying it (Bibi et al., 2020).

On the other hand, natural food colorings are very sensitive to the treatments used in the process (heat, acidity, light, preservatives, etc.), destroying themselves, so they must be replaced by more stable ones (Meena et al., 2021). Other foods, such as candies, or high-tech products that have recently appeared on the market such as seafood imitations, do not have any color of their own, and must be artificially colored to make them more attractive (Ramesh and Muthurama, 2018).

However, synthetic dyes warn of health risks, and as a consequence there is currently a growing search for new sources for the extraction of natural dyes such as betalains, chlorophylls, carotenoids and anthocyanins, among others, in order to replace the synthetic dyes, especially red ones (Fernández-López et al., 2020). Natural colors are generally considered to be innocuous and consequently the specific limitations on their use are less than those that affect artificial colors (Leong et al., 2018).

Using an AI-powered recommendation engine might help you connect with your ideal customers more effectively. Each user's individual tastes and interests shape the recommendations they get. Customers who care about the brand on a personal level are more likely to remain loyal during good times and bad. Customers of e-commerce sites may benefit from conversational interfaces and other forms of digital assistance. Real Language Processing is used to make sure the message gets over as accurately and individually as possible. Worse, they might be having actual conversations with your consumers in real time. Internet businesses have a number of challenges, but two of the most pervasive are credit card theft and bogus reviews. Credit card fraud might be reduced with the use of artificial intelligence (AI) tools that evaluate user behavior. People who are on the fence about a purchase often read reviews written by consumers who have previously made a transaction. It's possible that AI might be a useful tool in the battle against false ratings and comments.

Therefore, the joint assessment of the kinetic values will be essential to optimize the use of natural sources of color, where the kinetic equations can be used to estimate the stability during storage and therefore the useful life of the dye.

2.Materials and methods

2.1.Materials reactives

We worked with two formulations of hard candies (candies with extract coloring and candies with powder coloring), made with dyes extracted from the orange flowers of the cress. 40 units of hard candies were used; being 20 sample units of each dye.

2.2.Obtaining the dyes (extract and powder)

It refers to the extraction and physicochemical characterization of the natural pigment (anthocyanins). Obtaining performance. It was determined (pH, acidity, soluble solids, humidity, solubility, hygroscopicity and density).

2.3.Obtaining and evaluation of the experimental units

The goal of the research was to assess the kinetics of color deterioration in hard candies made using orange cress flower dye. The anthocyanin extract was combined with maltodextrin before being spray-dried to create experimental units in the shape of sweets. The color deterioration of these candies was then evaluated by measuring the a*, b*, and L* values throughout the course of 28 days of storage at various temperatures. The research showed that both candy formulations followed first-order kinetics with a range of temperature coefficients (Q10), decimal reduction times (D), mean degradation durations (t0.5), activation energies (Ea), and degradation rates (K). The results contributed to a better understanding of the performance of the dye as a coloring agent in food items by revealing important information about the color stability of the candies and their sensitivity to storage conditions.

2.4.Analysis of physicochemical properties

It was determined (pH, acidity, soluble solids, moisture, reducing sugars).

2.5.Analysis of physical properties

The L*a*b* values were determined according to the CIELAB system.

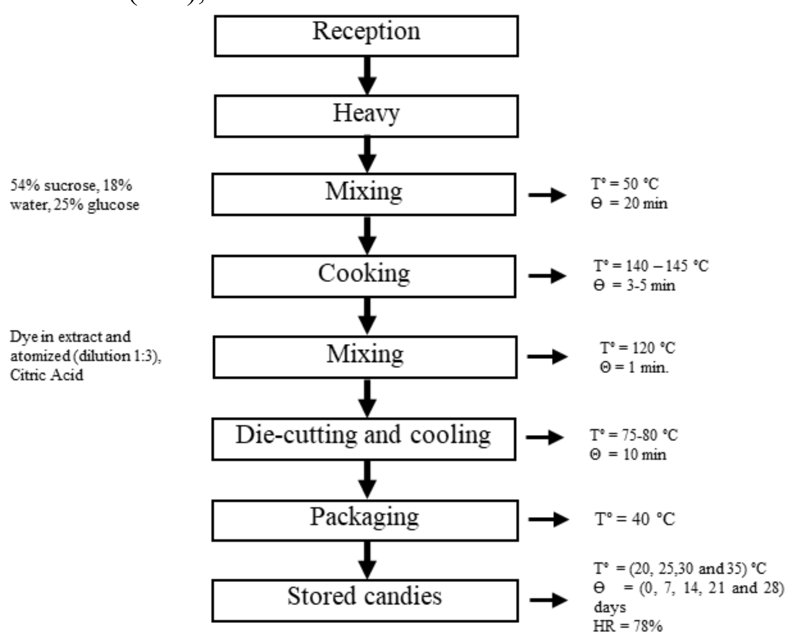

Figure 2. Flow diagram and experimental design of the kinetics of color degradation of hard candies.

2.6.Statistical analysis

The research data were evaluated with the ANOVA statistic of linear correlation, the analysis of variance was worked with 0.05 of significance; using the correlation coefficients (R) and regression coefficients (R^2). The data was processed with the help of the Microsoft Excel 2010 spreadsheet and the statistical program SPSS v. 23.

2.7.Analysis of Artificial Intelligence

An inexpensive optical gadget could be built on the ability to recognize colors mirrored in a surface. Models constructed using artificial neural networks are used to improve the color representation derived from sensory data. Analog data from the sensor are converted to the three main colors in a very efficient manner (RGB). In this research, we present an artificial intelligence programmer that can reproduce cooler data from the cooler sensor's mechanical outputs. In addition, inverse modelling, which is supported by an especially ingenious technique, allows a colorimetric sensor to be used in combination with the sensor probe. The sensor tool provides a voltage reading for detecting color changes.

2.8.Deep learning from physicochemical

Mixture design factors play a crucial role in many modern machine learning-based approaches to concrete research and design, allowing for more accurate prediction of concrete traits. However, the physical characteristics of components, such as the particle size distribution and the chemical composition of various substances and particles, are not considered by these techniques. The purpose of this piece is to describe a technique for figuring out how the physical properties of the constituents of concrete affect the compressive properties of the final product. This research proposes a robotic method of constructing deep learning models, develops an N-grams-based method of extracting features from text, and invents a fabricated language for talking about real objects and their actual qualities. Predicting the tensile strength of complicated concrete mixtures, weighing the significance of variables, and illuminating chemistry processes have all been shown to benefit from the proposed approach, demonstrating its high accuracy and generalizability. As a result of this research, we will be better able to produce low-cost, low-carbon-emission concrete without sacrificing our understanding of the underlying processes involved in creating complex concrete mixtures (See in Figure 3).

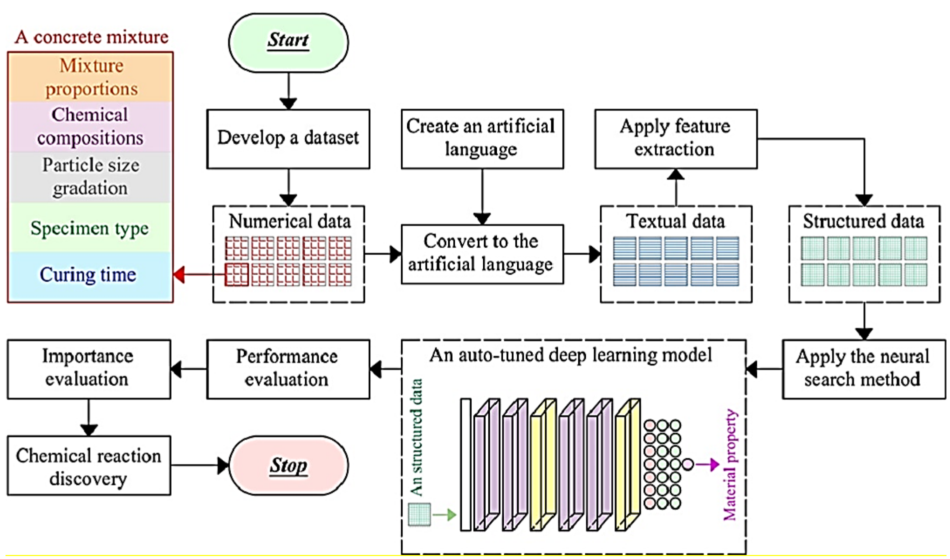

Figure 3. Deep learning from physicochemical

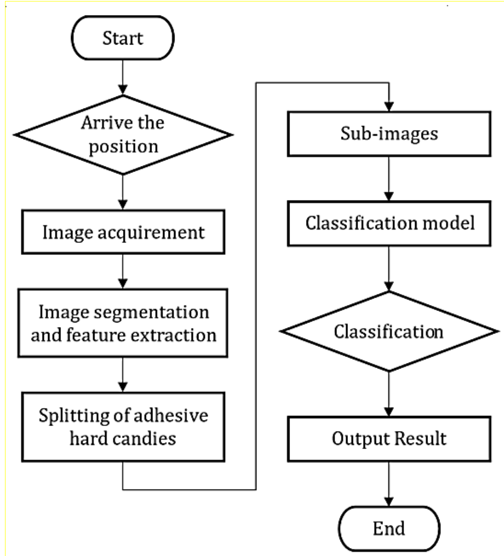

Figure 4. Classification of defective hard candies

2.9.Classification of hard candies

The following are the primary aspects that make up the technique for classifying hard candies, the discovery and separation of adhesive hard candies, which will be covered in the following section and the labelling of hard candies. Figure 4 depicts the primary stages involved in analyzing and classifying solid chocolates. These stages include: When the solid chocolates have been delivered to the specified location, an industrial camera is used to capture the initial picture. This occurs after the sifting process has been initiated. The technique of segmentation that is used to liberate solid chocolates that are trapped involves locating angular areas as a primary component. After the pictures have been preprocessed, a convolutional neural network model that has been trained for classification is given the sub-images of the different types of hard chocolates. This model is then able to classify the images. The outcomes of this classification will be displayed once it is finished.

3.Results and discussions

3.1.Extraction and physicochemical characterization of the dye (extract and powder) of the orange cress flower (*Tropaeolum majus L.*)

It was developed, as detailed in the methodology using simple tables; the results are reported in table 1.

Table 1. Physicochemical analysis carried out on the dye (extract and powder) of the orange cress (*Tropaeolum majus L.*) flower.

Analysis	Colorant	
	Extract	Powder
pH a 20 °C	1.34	3.52
°Brix a 20 °C	49.7	81.5
Titratable Acidity (% citric acid)	6.41	4.84
Moisture (%)	----	5.17
Solubility (%)	----	84.7
Density (mg/ml)	----	1.46
Hygroscopicity (%)	----	14.05

Table 1 shows that the powder dye has a high pH compared to the extract dye at 61.9%, the titratable acid content is higher in the extract dye at 24.5% compared to the dyes in dust; due to different factors such as spray drying and physical structure. In this regard, (Arrazola et a1., 2014) in the investigation about the influence of the inlet air temperature and the concentration of maltodextrins on the final humidity and anthocyanin content in the spray drying of cress flowers (*Tropaeolum majus L.*), reported that the extract presented a pH value of 1.7 and 6.5% of titratable acidity, while the powder presented a pH of 3.5, being almost the same as those obtained in the present investigation; This is because the same extraction method (acidified ethanol) was used.

Likewise, (Zapata et al., 2014) points out that in the series of solid-liquid extractions, acidified ethanol allows a better concentration of anthocyanins to be achieved; This is due to the fact that low pH values facilitate greater extraction yield and stability thanks to the formation of the flavylium cation (Moldovan et al., 2012). In this regard, Moldovan, (2012) in his research study mentions that at pH 1 the flavylium cation predominates, which is red in color and is the most stable form of anthocyanin, at pH values between 2 and 4 the loss of a proton occurs and addition of water, being the anthocyanins preferably under the quinodal forms of blue color. At pH between 5 and 6, the pseudobase species carbinol, which is colorless, and chalcone, which is yellow, are observed. At pH above 7, rapid degradation of anthocyanins occurs due to oxidation with air; because the flavylium nucleus is electron deficient and therefore highly reactive (Sharma et al., 2019). Affirming then that low pH contents are favorable in the extraction of anthocyanins, because acidity has a protective effect on the anthocyanin molecule by giving it greater stability (Chen et al., 2022).

Referring to soluble solids, it is reported that the dye in the extract contains 10.7% times greater than that indicated by (Arrazola et a1., 2014), where they reported a content of 39°Brix. However, this high concentration of sugars was favorable, since high concentrations of sugars stabilize anthocyanins (Fernandes et al., 2021). But, when the sugars are in low concentrations, the water activity is not affected, so their degradation products (hydroxymethylfurfural and furfural) accelerate the destruction of anthocyanins (Kopjar and Piližota, 2009). Then, since the water molecule intervenes in reactions that deteriorate anthocyanins, the high concentration of soluble solids was convenient to reduce the chances of nucleophilic attack on the flavylium cation.

The moisture content of the powder dye led to a lower hygroscopicity (14.05) than that reported by (Arrazola et a1., 2014) (% moisture 3.19 - 3.45; hygroscopicity 15.61 - 15.67); according to Han et al. (2020) is because humidity and hygroscopicity are inversely proportional. This event was observed by (Arrazola et a1., 2014) who mentioned that the atomized dye reported that at higher air inlet temperatures they are more hygroscopic, due to the lower moisture content in the dust (related to the water concentration gradient between product and surrounding air). However, Han et al. (2020) observed that hygroscopicity decreased in the temperature range of 188 to 190°C, indicating that hygroscopicity decreases at high temperatures. Hygroscopic foods have the ability to contain occluded moisture and it is an important characteristic to be considered during storage (He et al., 2019).

The solubility reported with respect to the powdered dye is similar to that reported by (Arrazola et a1., 2014), who reported their results between 80 and 98%, because it is influenced by the air inlet temperature in the drying, presenting more solubility as the temperature increases. Jittanit et al., (2011) observed that the drying temperature has a positive effect on solubility, since high air inlet temperatures produce more porosity in the powders. The increased porosity gives rise to a higher specific surface area of powder, which results in a larger contact area between powder and water.

Regarding the density of the powdered dye, it is within the values of 1.4286 to 1.6667 g/mL reported by (Arrazola et a1., 2014). In this regard, Caparino et al. (2012) mention that the higher the concentration of maltodextrin, the apparent density decreases, thus existing an inverse relation of the density, indeed this value is influenced by the type of encapsulating agent used in the investigation where maltodextrin was worked at 10% Dextrose equivalent.

3.2.Physical analysis of hard candy

Table 2 shows the analysis of the color in the candies subjected to different storage conditions and different presentation of the dye.

The table shows that the luminance (L*) and yellow and blue chromaticity (b*) increase, while the red and green chromaticity (b*) decreases, permanently at each kinetic value, the color of the edges being relatively less pronounced. candies with extract coloring and candies with powder coloring at higher temperatures and times, because the L*a*b* values represent the chromatic model that describes all the colors that the human eye can perceive (Casassa et al., 2021). Since according to Durmus, (2020) luminance indicates black when the values of L* are close to and/or equal to zero and indicates white when the values of L* are close to and/or equal to 100; for the yellow and blue chromaticity figures (b*), values close to zero indicate blue and values close to 100 indicate yellow; while in magenta and green chromaticity (a*) values adjacent to zero indicate green while values adjacent to 100 indicate magenta. Noting that the values shown in table 3 specify the degradative change of color, as it changes from a state of intense color to a less intense one.

Table 2. Physical analysis of hard candy with coloring (extract and powder) from the cress flower at different temperatures and storage times.

T (°C)	t (days)	Cielab Values (CCE)				Cielab Values (CCE)		
		L*	a*	b*		L*	a*	b*
20	0	37.09	35.93	20.76		36.27	36.46	23.67
	7	38.34	35.50	20.85		36.56	35.46	24.84
	14	39.53	34.39	21.32		37.19	34.27	25.70
	21	40.42	33.48	21.90		38.63	34.12	25.91
	28	41.13	32.25	22.54		39.36	33.25	26.84
25	0	37.09	35.93	20.76		36.27	36.46	23.67
	7	38.98	35.16	22.16		37.25	35.38	24.94
	14	39.62	32.97	22.35		37.40	35.11	25.71
	21	41.72	32.43	22.88		40.92	33.34	27.32
	28	42.16	31.42	23.43		41.31	31.88	27.47
30	0	37.09	35.93	20.76		36.27	36.46	23.67
	7	40.47	32.45	23.87		38.13	35.04	25.14
	14	40.71	31.63	24.18		38.64	34.46	29.28
	21	41.67	31.22	25.69		41.35	32.23	29.48
	28	42.77	29.65	25.94		42.61	28.46	30.60
35	0	37.09	35.93	20.76		36.27	36.46	23.67
	7	41.13	31.45	24.59		39.60	33.35	27.62
	14	41.19	31.39	25.45		40.71	32.99	28.12
	21	42.02	29.11	27.88		42.77	30.24	29.77
	28	47.34	26.11	28.12		44.57	26.89	32.29

legend: *L* = luminance; a* = yellow and blue chromaticity; b* = magenta and green chromaticity.*

Table 3 reports that the degradation responds to first-order degradation kinetics, as evidenced in the regression coefficients greater than 85.6% and 88.7%; and in the correlation coefficients greater than 92.5% and 94.2%. This high manifestation in the coefficients indicates a high degree of linear relationship between the luminance concentration and the time in a directly proportional way.

The regression p-value (≤ 0.05) obtained by the first-order model equation for candies with extract coloring and candies with powder coloring at all heating temperatures indicated that the fit of the model was significant (Table 4). In addition, it can be observed in figures 4 and 5 that the trend of the experimental data and those predicted by the model are almost the same, which would anticipate the suitability of the model.

Table 3. Summary of the statistical model to establish the association of the time variable with respect to the luminance concentration at different storage temperatures.

Product	Treatments	Correlation coefficient (R)	Regression coefficient (R^2)	Sig.
CCE	20°C 25°C 30°C 35°C	0.993 0.980 0.925 0.927	0.983 0.960 0.856 0.859	0.001 0.003 0.024 0.023
CCP	20°C 25°C 30°C 35°C	0.975 0.942 0.985 0.983	0.951 0.887 0.970 0.967	0.005 0.017 0.002 0.003

Legend: *CCE = Candies with coloring in extract; CCP = Candies with powder coloring.*

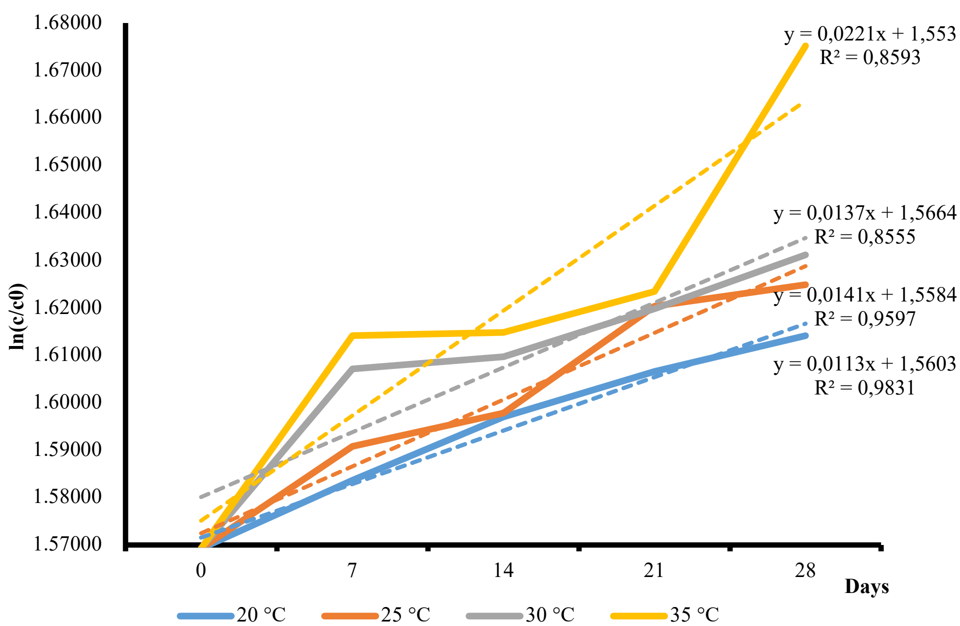

Figure 5. Thermal degradation kinetics of the luminance (L*) of hard candy, including the colorant in extract.

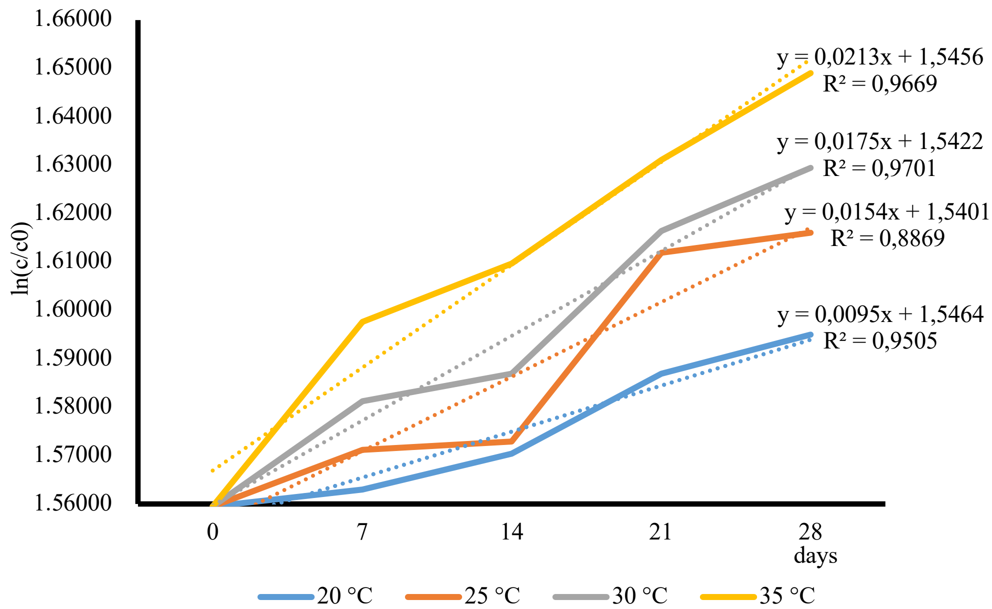

Figure 6. Thermal degradation kinetics of luminance (L*) of hard candy, including powdered colorant.

Likewise, Devi et al. (2012) when carrying out studies on the degradation of anthocyanins, mention that they obtained anthocyanin extracts from 4 species of barbaries and stored it for 84 days at temperatures of 5 - 35 °C, observing that the deterioration of anthocyanins increases with the increase of the temperature.

On the other hand, Pereira Miti, (2020), carried out a study on the kinetics of anthocyanin degradation during the heat treatment of blueberry juice, between temperatures of 40 and 80 °C, pointed out that this was of the first order and that the degradation was higher at higher temperature values.

Pereira et al., (2010) also studied the kinetics of anthocyanin degradation, in this case in blackberry juice, during heat treatment and storage. There was a loss of anthocyanins, both during heat treatment and during storage. This loss followed first-order kinetics. Furthermore, anthocyanin degradation increased with increasing temperature.

These bibliographical references would be showing that the choice of a first-order model to describe the kinetics of the degradation reaction of the L*a*b* values in hard candies including the coloring (extract and powder) during the storage is adequate.

3.2.Determination of the kinetic parameters K, D, Z, Q10, Ea and $t_{0.5}$ of the degradation of the color in the hard candies with inclusion of the coloring of the flower of the Cress (*Tropaeolum majus L.*) orange color.

Table 4. Color kinetic parameters as a function of the luminance (L*) of hard candies.

Product	T (°C)	K (days^{-1})	$t_{0.5}$ (days)	D (days)	Q10	Z (°C)	Ea (Kcal/mol)
CCE	20	0.00368	188.110	625.00	1.517	55.249	7.436
	25	0.00461	150.488	500.00			
	30	0.00461	150.488	500.00			
	35	0.00737	94.055	312.50			

CCP	20	0.00322	214.983	714.28	1.622	47.619	8.700
	25	0.00507	136.807	454.54			
	30	0.00576	120.390	400.00			
	35	0.00691	100.325	333.33			

Legend: CCE = Candies with coloring in extract; CCP = Candies with powdered coloring; T = Temperature; K = Relative rate of thermal degradation; $t_{0.5}$ = half-life time; D = Decimal reduction time; Q10 = Temperature coefficient; Z = Heat resistance capacity; Ea = Activation energy.

According to the first-order model that is evidenced by the regression and correlation coefficients in table 3 for hard candies, they show that the relative speed of thermal degradation of luminance (table 4) in candies with coloring in extract increase by 50.7% with respect to temperature changes from 20ºC to 35ºC, similar behavior is observed in the luminance of candies with powdered coloring, increasing by 53.6%, it should be noted that in the latter formulation there is a higher degradation constant. As evidenced by Chen et al., (2019) when obtaining aqueous extracts of sweet potato anthocyanins at pH 3 and storing it at 25°C. These authors calculated, for a first order model, degradation rate constants of 0.0168 and 0.0072 days^{-1}, depending on the variety. The same study was carried out on concentrated aqueous extracts of grapes and purple carrots, in which the degradation rate constants were 0.1585 and 0.0024 days^{-1}, respectively.

Likewise, the values of the degradation rate constant (k) obtained in the present investigation for the candies with coloring in extract and the candies with coloring in powder, stored at 25°C, presented speeds lower than those published by the aforementioned authors. for aqueous extracts. Indicating that what was obtained in our research was less sensitive to temperature, due to the type of process, the biological matrix of the object of study, its geometry and probably due to differences in the moisture content of the experimental units.

Table 4 shows the half-life time ($t_{0.5}$) where it decreases with increasing temperature. This parameter was higher in the candies with extract coloring by 3.4% compared to the candies with powder coloring, indicating that the first formulation has a longer useful life.

In this regard, Noman (2022) obtained half-life times of anthocyanins present in blackberry juices at 8.90°Brix and stored at 5 and 25°C of 330 and 32 days, respectively, and for blackberry juice at 65°Brix of 139 days. when the storage temperature was maintained at 5°C and 20 days, when it was at 25°C. Chen et al., (2019) calculated, for aqueous extracts stored at 25°C, half-life times of 41 and 2.5 days for purple sweet potato; 47 days for grapes and 216 days for purple carrots. For their part, Montibeller et al. (2018) when extracting anthocyanins from grape skins, concluded that the loss of anthocyanins increased with storage time. At 24°C the loss of anthocyanins was 7.73% on day 1 of storage and 37.19% on day 14; behavior that became more noticeable when the storage temperature rose.

Likewise, the half-life times, obtained for luminance (color) of the candies including the dyes (extract and powder), were higher by almost 10 months with respect to 25°C, compared to the aforementioned authors. Probably, this difference was due to the effect of the higher water content in the blackberry juice and in the aqueous extracts with respect to the hard candy, since the water acts as a nucleophile attacking the flavylium cation of the anthocyanins.

From the above, the feasibility of industrial use of the dyes obtained in this investigation is affirmed, since under conditions of technological process and storage at 20°C it would present an average useful life of 13 months, corresponding to the useful life of the candies. hard (1 – 2 years) according (Aranda-González et al., 2015)

In this regard, Table 4 shows that the decimal reduction time decreases for candies with extract coloring by 50% and for candies with powder coloring by 53.4%, which corroborates that as the temperature increases the concentration of the luminance values decreases gradually as the storage time elapses, being higher in candies with powdered coloring. Rosales (2010) mentions that the greater the decimal reduction time (D), the greater the luminance retention, because the decimal reduction time (D) is also an indicator of thermoresistance. Affirming that the candy with coloring in extract had a greater stability of 3.4% compared to the candy with powder coloring.

According to Rosales (2010) the heat resistance capacity (Z) is defined as the heat resistance capacity of the different nutrients, it is the number of degrees Celsius that corresponds to the change of the decimal reduction time (D) in its tenth power. , in addition Agbo et al., (2021), point out that the Z value is equal to the inverse of the slope of the relationship that exists between temperature and its D values, the higher the Z value, the greater the thermal resistance of the nutrient.

From the equation obtained in the linear regression of figures 7 and 8, it is evident that the correlation index for the thermal resistance capacity (Z) is 0.846 for candies with extract coloring and 0.92 for candies with powder coloring, indicating that there is a high degree of significance in the relationship between the inverse of the decimal reduction time and the temperature.

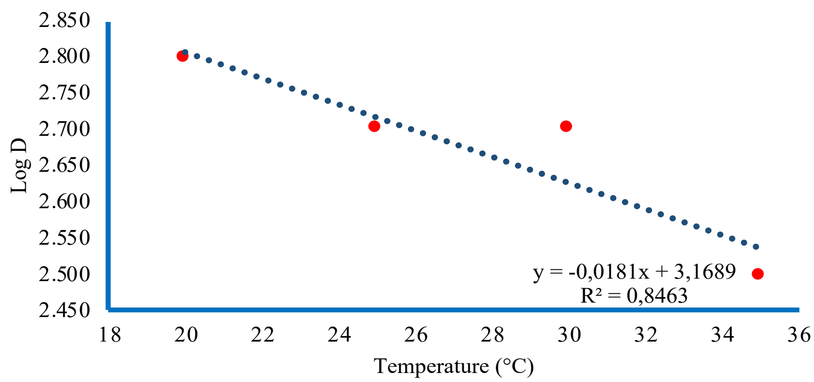

Figure 7. Logarithm of decimal reduction time (D) vs. the temperature (°C), in the candies with coloring in extract.

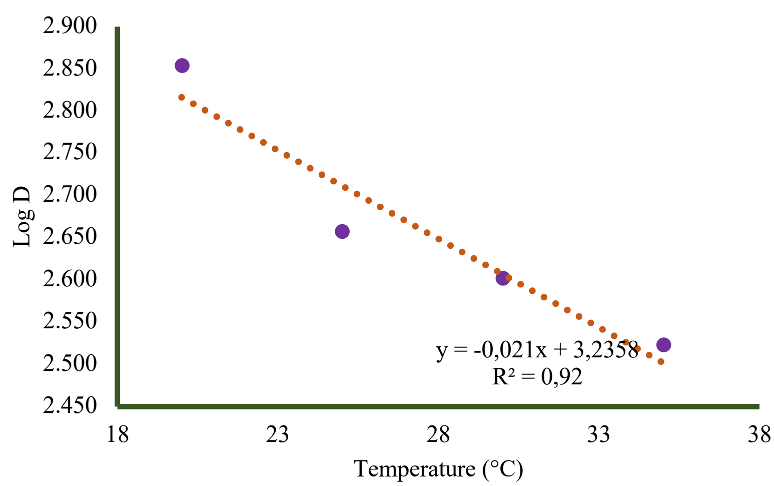

Figure 8. Logarithm of decimal reduction time (D) vs. temperature (°C), in candies with powder coloring.

The capacity of resistance to heat (Z) indicated in table 4 indicates that the candies with coloring in extract notice a greater resistance to the increase in temperature by 13.8% compared to the candies with coloring in powder; which corroborates the stability of the luminance present in the candies with extract coloring compared to the candies with powder coloring in the evaluated storage time.

The effect of temperature on different systems can be quantified by calculating the Q10 temperature coefficient, which indicates the rate of change of a process or reaction when the temperature varies by 10°C (Mundim et al., 2020).

The values obtained from Q10 reported in table 5 indicate that the luminance degradation kinetics was 6.17% higher in the candy with powdered coloring compared to the luminance of the candies with extract coloring. In this regard, Pereira et al., (2010) mention in the degradation of anthocyanins in blueberry juice, the Q10 values are higher in the temperature range between 40 and 50°C (Q10 = 4.27) and the lowest values in the intervals between 60 and 70°C (Q10 =1.67) and 70 and 80°C (Q10=1.67). Affirming that the reaction speed in the luminance of the candies with coloring in the extract corroborates the kinetic parameters found previously (k, $t_{0.5}$, D and z).

The Arrhenius equation is usually applied to evaluate the effect of temperature on the rate constants of different types of reactions (Encinar et al., 2018). For reactants to become products, they must reach a minimum energy called activation energy (Ea).

In the present work, the Arrhenius equation was adjusted to the relative rate constants of thermal degradation (k) identified at each of the treatment temperatures. The high correlation coefficients of 0.839 for candies with extract coloring and 0.926 for candies with powder coloring indicate a high correlation between the logarithm of the relative rate of thermal degradation (ln k) and the inverse temperature (1/T). (Figure 7 and 8) and therefore a good fit of the Arrhenius model. Equation by which the activation energy necessary to achieve degradation was calculated, being the candies with extract coloring greater by 14.5% than the candies with powder coloring, which indicates that more energy is required to start the process. deterioration of luminance, therefore the degradation of anthocyanins presents in candies with powder coloring than in caramel with extract coloring, since according to Zapata (2014), once the anthocyanin molecules have managed to reach activation energy (Ea) the deterioration of the pigments occurred faster in the candies with powder coloring than in the candies with extract coloring. Various investigations on anthocyanin degradation kinetics, such as those reported by Pereira Oancea et al., (2021) in blueberry juice, mention that they obtained an activation energy of 80.42 kJ/mol, while Miti, (2020) obtained a activation energy of 58.95 kJ/mol when studying the degradation of anthocyanins in blackberry juice. Therefore, the energy needed to initiate the degradation of anthocyanins present in candies were 42% lower than that published for blackberry juice and 57% for blueberry juice, due to factors such as the biological matrix, temperatures and experimental unit.

Chemical kinetics aims to predict the speed of chemical reactions and describes their course (Dahm & Brezonik, 1995) and the factors that affect the reaction speed are mainly the nature and concentration of the reacting substances (reagents). the temperature and the catalysts, this was evidenced in the present investigation.

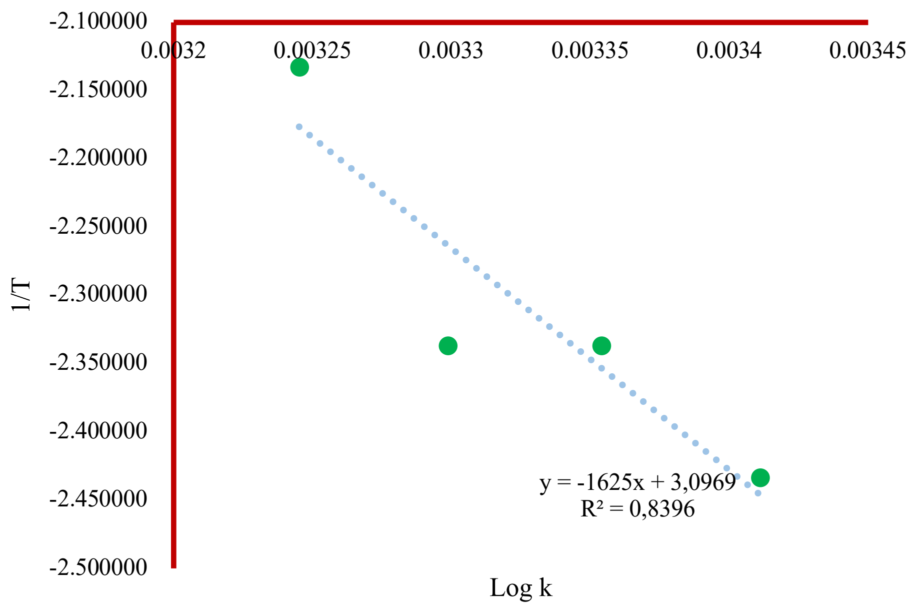

Figure 9. Arrhenius equation for the thermal degradation of the luminance (L*) of hard candy, using the dye in extract.

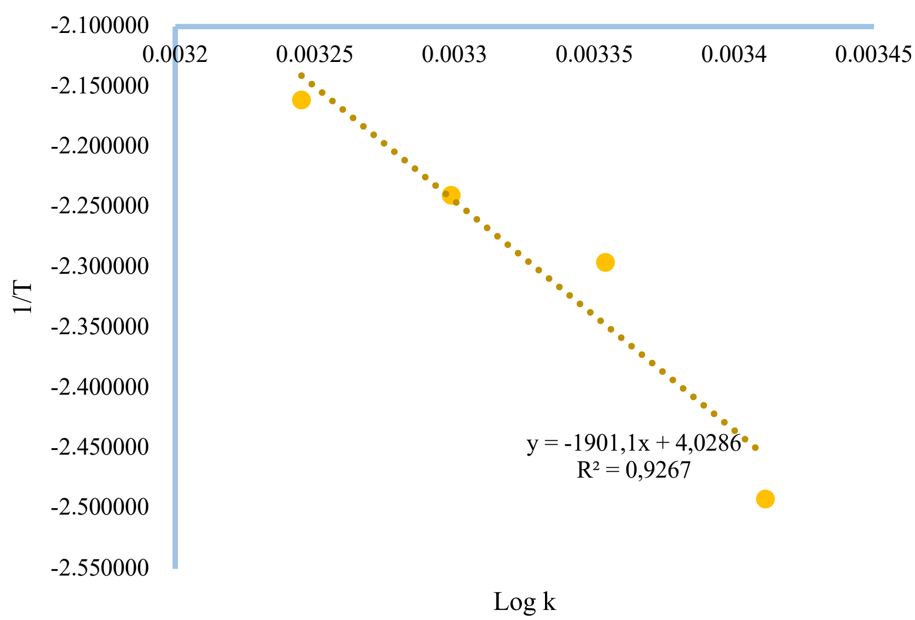

Figure 10. Arrhenius equation for the thermal degradation of the luminance (L*) of hard candy, using the powdered coloring.

4.Conclusions

It is evident that there is a significant relationship between storage time and the kinetics of color degradation of hard candies with the addition of coloring from the cress flower because the p-value for candies with coloring in extract was 0.001 to 0.023 and for candies with powdered coloring it was from 0.005 to 0.017; The relationship level is highly positive because Pearson's r for candies with extract coloring was 0.925 to 0.993 and for candy with powdered coloring it was 0.942 to 0.983, which follows first-order kinetics.

The mean degradation time ($t_{0.5}$) varied from 94 to 188 days for the candies formulated with the extract coloring and between 100 and 215 days for those formulated with the powder coloring.

Using an AI-powered recommendation engine may help you better engage your target audience. Users' individual tastes and interests are taken into account throughout the suggestion process. Those who have a personal connection to the company are more likely to remain loyal during both good and bad times. The usage of conversational interfaces and other forms of digital assistance in e-commerce may be helpful to consumers. Real Language Processing is used to make sure the message gets through as accurately and personally as possible. Worse still, they may actually have live conversations with your consumers. Credit card theft and bogus reviews are two of the most pressing problems facing online businesses today. Technology using artificial intelligence (AI) to evaluate user behavior might be useful in the fight against credit card fraud. Many people who are thinking about buying something rely on reviews written by those who have previously purchased the item. An effective tool in the battle against false ratings and comments might be artificial intelligence (AI).

5.References

Agbo, E. P., Ekpo, C. M., & Edet, C. O. (2021). Analysis of the effects of meteorological parameters on radio refractivity, equivalent potential temperature and field strength via Mann-Kendall test. *Theoretical and Applied Climatology*, Vol. 143(3), pp. 1437-1456.

Bibi, S. N., Montesano, D., Albrizio, S., Zengin, G., & Mahomoodally, M. F. (2020). The versatility of antioxidant assays in food science and safety—Chemistry, applications, strengths, and limitations. *Antioxidants*, Vol. 9(8), pp. 709.

Dahm, C., & Brezonik, P. (1995). Chemical Kinetics and Process Dynamics in Aquatic Systems. *Journal of the North American Benthological Society*, *14*, 354..

Cai, R. and Chi, C.G.-Q. (2020), "A recipe for food promotion: effects of color brightness on food evaluations and behavioral intentions", International Journal of Contemporary *Hospitality Management*, Vol. 32 No. 12, pp. 3925-3947.

Caparino, O. et al. (2012). Effect of drying methods on the physicalproperties and microstructures of mango (Philippine Carabao var.) powder. *Journal of Food Engineering*, Vol *111*(1), pp. 135-148.

Casassa, L. F., Bolcato, E. A., Sari, S. E., & Barda, N. (2021). Effects of maceration length after prefermentative cold soak: Detailed chromatic, phenolic and sensory composition of cabernet sauvignon, malbec and merlot wines. *Journal of Food Composition and Analysis*, Vol. 104, pp. 104168.

Chen, C. C., Lin, C., Chen, M. H., & Chiang, P. Y. (2019). Stability and quality of anthocyanin in purple sweet potato extracts. *Foods*, 8(9), 393.

Chen, X., Guan, Y., Zeng, M., Wang, Z., Qin, F., Chen, J., & He, Z. (2022). Effect of whey protein isolate and phenolic copigments in the thermal stability of mulberry anthocyanin extract at an acidic pH. *Food Chemistry*, 377, 132005.

Arrazola, G., Herazo, I., & Alvis, A. (2014). Microencapsulación de Antocianinas de Berenjena (Solanum melongena L.) mediante Secado por Aspersión y Evaluación de la Estabilidad de su Color y Capacidad Antioxidante. *Información tecnológica*, *25*(3), 31-42.

Devi, S.P., Saravanakumar, M., Mohandas, S. (2012). The effects of temperatura and pH on stability of anthocyanins from red sorghum (Sorghum bicolor) bran. *African Journal of Food Science*, 6: 567-573.

Durmus, D. (2020). CIELAB color space boundaries under theoretical spectra and 99 test color samples. *Color Research & Application*, 45(5), 796-802.

Encinar, J. M., Pardal, A., Sánchez, N., & Nogales, S. (2018). Biodiesel by transesterification of rapeseed oil using ultrasound: a kinetic study of base-catalysed reactions. *Energies*, 11(9), 2229.

Fernandes, A., Raposo, F., Evtuguin, D. V., Fonseca, F., Ferreira-da-Silva, F., Mateus, N., ... & de Freitas, V. (2021). Grape pectic polysaccharides stabilization of anthocyanins red colour: Mechanistic insights. *Carbohydrate Polymers*, 255, 117432. https://doi.org/10.1016/j.carbpol.2020.117432

Fernández-López, J. A., Fernández-Lledó, V., & Angosto, J. M. (2020). New insights into red plant pigments: More than just natural colorants. *RSC advances*, 10(41),

Han, J., Liu, X., Chen, D., & Jiang, M. (2020). Influence of relative humidity on real-time measurements of particulate matter concentration via light scattering. *Journal of Aerosol Science*, 139, 105462.

He, Z., Qian, J., Qu, L., Yan, N., & Yi, S. (2019). Effects of Tung oil treatment on wood hygroscopicity, dimensional stability and thermostability. *Industrial Crops and Products*, 140, 111647.

Jittanit, W., Chantara M., Deying, T. y Ratanavong, W. (2011). Production of tamarind powder by drum dryer using maltodextrin and arabic gum as adjuncts. *Songklanakarin Journal of Science and Technology (SJST)*. p. 33-41.

Kopjar, M., Piližota, V. (2009). Copigmentation effect of phenolic compounds on red currant juice anthocyanins during storage. *Croatian Journal of Food Science and Technology*,1: 16-20.

Leong, H. Y., Show, P. L., Lim, M. H., Ooi, C. W., & Ling, T. C. (2018). Natural red pigments from plants and their health benefits: A review. *Food Reviews International*, 34(5), 463-482.

McDonald, S. T. (2018). A review of color flavor interaction in food and its application in food product development. *Advances in Food Technology Nutrition Science Open Journal*, 4(1), 23-27.

Meena, M., Prajapati, P., Ravichandran, C., & Sehrawat, R. (2021). Natamycin: a natural preservative for food applications—a review. Food Science and Biotechnology, 30(12), 1481-1496.

Miti, M. (2020). Kinetic and thermodynamic characteristics of thermal degradation of anthocyanins from strawberry and blueberry commercial juices kinetic and thermodynamic characteristics of thermal degradation of anthocyanins from strawberry and blueberry commercial juic. Chem. *Naissensi*, 3, 46-63.

Moldovan, B., David, L., Chişbora, C., Cimpoiu, C. (2012). Degradation kinetics of anthocyanins from european cranberrybush (Viburnum opulus L.) fruit extracts. Effects of temperature, pH and storage solvent. *Molecules* 2012, 17, 11655-11666.

Montibeller, M. J., de Lima Monteiro, P., Tupuna-Yerovi, D. S., Rios, A. D. O., & Manfroi, V. (2018). Stability assessment of anthocyanins obtained from skin grape applied in kefir and carbonated water as a natural colorant. *Journal of Food Processing and Preservation*, 42(8), e13698.

Mundim, K. C., Baraldi, S., Machado, H. G., & Vieira, F. M. (2020). Temperature coefficient (Q10) and its applications in biological systems: Beyond the Arrhenius theory. *Ecological Modelling*, 431, 109127.

Noman, A. A. (2022). Development of guava-strawberry jelly and analysis of its physico chemical properties and bioactive compound (Doctoral dissertation, Chattogram Veterinary & Animal Sciences University).

Oancea, S. (2021). A review of the current knowledge of thermal stability of anthocyanins and approaches to their stabilization to heat. *Antioxidants*, 10(9), 1337.

Pereira Kechinski, C., Ramos Guimaraes, P., Zapata Noreña, C., Tessaro, I., Ferreira Marczak, L. (2010). Degradation kinetics of anthocyanin in blueberry juice during thermal treatment. *Food Science*, 75: 173-176.

Ramesh, M., & Muthuraman, A. (2018). Flavoring and coloring agents: Health risks and potential problems. In Natural and artificial flavoring agents and food dyes (pp. 1-28). *Academic Press*.

Aranda-González, I., Tamayo-Dzul, Ó., Barbosa-Martín, E., Segura-Campos, M., Moguel-Ordoñez, Y., & Betancur-Ancona, D. (2015). Desarrollo de una golosina tipo" gomita" reducida en calorías mediante la sustitución de azúcares con Stevia rebaudiana B. *Nutrición Hospitalaria*, *31*(1), 334-340.

Rosales, H. (2010). Conservación de alimentos por calor, cinética de la destrucción térmica. Universidad nacional del centro del Perú. *Facultad de Ingeniería en Industrias Alimentarias. Huancayo – Perú.*

Sharma, P., Jha, A. B., & Dubey, R. S. (2019). Oxidative stress and antioxidative defense system in plants growing under abiotic stresses. In Handbook of Plant and Crop Stress, Fourth Editspenion (pp. 93-136). *CRC press*.

Gallace, A., Boschin, E., & Spence, C. (2011). On the taste of “Bouba” and “Kiki”: An exploration of word–food associations in neurologically normal participants. *Cognitive Neuroscience*, *2*(1), 34–46.

Tijskens, P., & Schouten, R. (2022). Modeling quality attributes and quality-related product properties. *In Postharvest handling* (pp. 99-133). Academic Press.

Zapata, L. M., Heredia, A. M., Quinteros, C. F., Malleret, A. D., Clemente, G., & Cárcel, J. A. (2014). Optimización de la extracción de antocianinas de arándanos. *Ciencia, docencia y tecnología*, (49), 166-192.

Conflicts of Interest

There are no competing interests.

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3. Franklin Ore Areche: development of the experimental part of the Research.
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11. Héctor Lorenzo Villa Cajavilca: Writing and application of syntax in the scientific article