Studies of the Correlation Between the Physicochemical and Sensory Properties of Fried Doughnut Affected by the Added Green Tea Infusion and Ascorbic Acid with the Use of Principal Component Analysis

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ABSTRACT

In the present study the behaviour and alterations in physicochemical and sensory parameters of fried Doughnut affected by the added green tea infusion with different concentrations of (0, 100, 150 and 200 ppm) and ascorbic acid (0, 50,100, 150 ppm), were studied with the use of Principal Component Analysis. The achieved results showed the effect of those compounds on peroxide index and radical scavenging activity. Moreover the alterations between the studied parameters and their relationships were detected negatively on the peroxide index of the product. On the other hands, the addition of green tea infusion and ascorbic acid showed that, they might affect positively on the samples and create novel relationships among the studied parameters of the products. Also, the achieved outcomes have not presented synergistic effects of ascorbic acid on green tea infusion in the concentration of 50 ppm. While the higher level of ascorbic acid in the concentration of (100 and 150 ppm), in the presence of three concentrations of the green tea, presented considerable effects on the general acceptance among different parameters detected with the use of Principal Component Analysis. On the other hand the tiny presence of the green tea infusion as well as ascorbic acid in the extracted oil presented more predominant effect of green tea infusion on the studied physico-chemical properties of the product in comparison to ascorbic acid.

Key Words: Antioxidant, Texture, Image processing, Main Component Analysis, Oil

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INTRODUCTION

Doughnut is a type of a fried sweet made from wheat flour that in many cases is prepared and consumed in various shapes in different countries as a snack due to its attractive taste and being energetic. Initially it was prepared in Germany and Netherland [1,2]. This product based on its textural properties is categorized in the fried and gelatinized groups. The fried part is prepared by the direct contact to the oil. This part due to having tender texture and golden brown colour has the highest range of oil absorption and the moisture repulsion. The internal part achieved by starch gelatinization process has two types of texture including soft and porous [3]. The oil application in food products might reach 50% of total weight of the product, in Doughnut, based on its formulation and processing conditions, it might reach the range of 10-26% [4]. Regarding the highest quantity of unsaturated fatty acids in Doughnut's texture, the achieved product might lose its physicochemical and nutritional properties due to oxidation reactions. The produced byproducts by oxidation are considered as the most considerable parameters in revealing undesirable alterations in taste, odor and appearance of the obtained products and as a result reduce

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the obtained products' acceptance among customers [5]. Therefore, the application of antioxidants as delaying and controlling agents against oxidation reactions in the products has attracted more attention these days. In this regard, the commercial antioxidants including butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT) categorized in synthetic antioxidants are extensively used to reduce the oxidation rate of oils in food products. However the unhealthy properties of the synthetic antioxidants have been proved by different studies [6, 7]. Thus discovering and application of natural antioxidants in food products are very important. Natural antioxidants including Tocoferols, Carotenoids and ascorbic acid have been known from ancient time and many studies have been performed on different properties of these antioxidants [8-10]. Phenols are other compounds with bioactivity [11]. These compounds along with having acceptable antioxidant activities that increases shelf life of foods might also enhance the health properties of the products. The green tea due to containing Cathechins (Epigallocatechin gallate and Epicatechin gallate) is considered as a considerable source of natural antioxidants [12]. On the other hand, the performed studies have shown the synergistic effect of ascorbic acid on the antioxidative activities of phenolic compounds of green tea [13; 14]. Furthermore, the addition of ascorbic acid in cereal flour based dough might improve the technological and sensory properties of the final produced product [15]. Therefore, the addition of green tea in combination of ascorbic acid in the initial formulation of Doughnut with the established health properties, might improve the qualitative and quantitative properties of the final products with the use of synergistic properties. In the current research, the effects of the added green tea infusion and ascorbic acid on the produced Doughnut properties with the use of Principle Component Analysis (PCA) as one of the important multi factorial data analysis have been studied. The aim of the present study is to research the correlation between the technological and sensory properties of the produced Doughnut enriched by natural antioxidants including green tea infusion and ascorbic acid. In other words with the use of Principle Component Analysis (PCA), the hidden and unrecognized behaviors among different properties of the products might be studied to clarify the alteration's rate and relationships between different studied parameters.

MATERIALS AND METHODS

The green tea leaves have been washed with distilled water, ground (with an electrical grinder model National, K039131) and sieved (mesh size of 0.425 mm) until reaching uniform particles. The obtained particles were mixed with distilled water with the proportion of 1/35, then the mixed and stirred well with the rate of 70 RPM. The prepared suspension was filtrated with the use of a Whatman filter paper. Afterward the filtrated infusion was concentrated with the use of a rotary evaporator (Model Strike 202-Made in Italy) with the rate of 66 RPM, temperature of 60 ℃ for 43 minutes until reaching suspension with the value of brix equals to 40. Then the concentrated suspension was dehydrated by 4% based on dry weight with the use of a rotary evaporator (Model VO 400-Made in Germany), in temperature below 40 ℃. Finally the obtained samples were sealed and preserved in glass containers by the experimental day [16].

Doughnut's dough preparation

White flour (degree of extraction equals to 77%) was provided from Gholmakan factory (Mashhad-Iran), active dry yeast (Saccharomyces cerevisiae) was purchased from Razavi factory (Mashhad-Iran), improver was collected from Delsa food industry factory with commercial name of Poyesh (Mashhad-Iran), oil was bought from Narges oil company (Shiraz-Iran). Further materials including sugar, salt as well as vanilla were purchased from local market in Mashhad (Iran). The compounds and materials including green tea infusion and ascorbic acid in the concentrations of 0, 100, 150, 200 ppm and 0, 50, 100, 150 ppm have been applied respectively. The ingredients of the prepared dough as well as oil without synthetic antioxidants were mixed with the rate of 120 RPM (using a standard mixture model Hugel, No. HG550TMEM), after the primitive fermentation process for 45 min was completed (at temperature equals to 40 ℃ and relative humidity of 80%), the obtained dough has been spread manually and was formatted with internal and external diameters equals to 2.5 and 6 cm respectively. The final fermentation stage was performed in specific conditions (for 15 minutes at 40 ℃ and relative humidity of 80%). After that, the samples were fried in a fryer (Model Black & Decker, Type 01) for 4 minutes at 150 ℃. The fryer tank was filled by 1.5 liter of oil. To establish the oil temperature, the fryer was turned on 1 hour before the frying process. The produced samples after cooling down at room temperature (20 ℃), were packed and preserved for 30 minutes in PET containers [2,17]. It should be mentioned that the secreted oil in Doughnut surface after frying and prior cooling down, was removed with the use of an Absorbent tissue. The standard samples were prepared with the use of commercial oils containing synthetic antioxidants.

Peroxide Index

The peroxide index was determined with the use of the approach described previously with the use of the following equation [18].

$$PV = \frac{(Aa - Ab) \times m}{55.84 \times W \times 2}$$

Where, PV presents peroxide index, Aa indicates the absorbance of the sample in the wavelength equals to 500 nm, Ab demonstrates the absorbance of the standard in the wavelength equals to 500 nm, m is the achieved slope by the calibration curve (40.86 with Explanation factor equals to 0.99) and W expresses the oil weight.

The colour parameters of the surface and central layer of the achieved Doughnut

The colour parameters of surface and central parts were detected via three parameters including L^*, a^*, b^*. L^* parameter shows the brightness of the sample in the range of 0 for pure back to 100 for pure white colour. a^* parameter presents proximity between the green and red colors in the range of -120 for pure green to +120 for pure red. b^* parameter defines the proximity between the blue and yellow colour in the range of -120 for pure blue to +120 for pure yellow. To determine these parameters, pieces with the size (area) of 2×2 cm from the surface and internal parts with the use of an electric saws (model 41600, 120 w) were collected, then with the use of a scanner (model HP Scanjet G3010), images were taken with the clarity of 300 pixel. Thereafter the taken images were evaluated with the use of LAB space in part Plugins of the mentioned software, and the aforementioned colour parameters were determined [19].

Porosity

To evaluate the porosity value of Doughnut's internal part, the analysis technique was applied. For this purpose, pieces in the size (area) of 2×2 cm of internal part of the produced Doughnuts were provided with the use of an electric saws (model 41600, 120 w), then using a scanner (model HP Scanjet G3010), the required images were taken with the clarity of 300 pixel. The taken images were analyzed by Image J (ordered by National Institute of Health-the USA), with activation of part Bit of the software, and the gray images were created. To convert the gray images to Binary ones, Binary section of the software got activated. These images are a collection of bright and dark points where the proportion of bright points to dark ones is an index of the porosity of the samples. It is obviously understood that, the more proportion the more porosity of the achieved breads might exist. Actually with activation of the relevant part of the software, this proportion might be determined and as a result, the porosity value of the samples could be measured [20].

Moisture content

To determine this value, the AACC 2000, pages 16-44 and the following equation was applied. For this purpose the samples were placed into an oven (Jeto Tech, model OF-O2G, made in South Korea) with the temperature of 100-105 ˚C.

$$MC = \frac{m1 - m2}{m0} \times 100$$

Where m_0 indicates the samples' weight, m_1 expresses the weight of the plate plus sample before placing in oven and m_2 demonstrates the plate's plus sample's weight after passing oven stage.

Water activity (a_w)

The water activity of the samples have been detected with the use of an equipment (Novasina ms1-aw, model AXZIR Ltd, made in Switzerland) after the samples were cooked and cooled down to 20 ˚C [21].

Volume of Doughnut

To detect the volume of the produced Doughnut, Rape seed displacement has been applied according to AACC 2000 standard number of 72-10. For this purpose a piece of Doughnut (2×2 cm) was provided and its volume was determined.

Texture

The texture of the samples has been studied using a texturometer (Farnell Model QTS-CNS made in UK) and Squeeze test. In this regard, uniform cubic pieces with dimensions of 2×2×2 cm were collected. Then a tubular probe made from aluminium with the diameter of 25 mm with the rate of 1 mm. s^{-1} started moving, after the direct contact of it with the samples' surface, 75% of the height of the samples were compressed [22].

Sensory evaluation

For this purpose, 10 different juries from faculty of Khorasan Razavi Agricultural Research and Education Center (Mashhad-Iran) according to triangular test and Gacula and Singh (1984) [23] approach, were determined. Afterward, the sensory properties of Doughnut and the presence of internal porosity and space as well as further sensory properties of Doughnut including form and shape (Asymmetric shape, tear or lose in some parts of Doughnut), the upper part's properties of doughnut including burn, abnormal colour, wrinkles and abnormal surface, the properties of the internal parts (burnt parts, wrinkled surface), porosity (abnormal porous, high compression and density), the softness and hardness (dough shape or unusual softness, stiffness, brittleness), chewing ability, odor and taste, have been detected and ranked as the following respectively 4, 2, 1, 2, 2, 3, 3 where 1 expresses the weakest and 5 indicates the highest or the most acceptable score. With having these scores, the general acceptance (doughnut quality) has been determined with the use of the following equation

$$Q = \frac{\sum(P \times G)}{\sum P}$$

Where Q presents the general acceptance, p indicates the attribution ratio and G shows the attributed evaluation coefficient.

Statistical analysis

To study the relationship between different detected parameters in the current study and the results of the replacement of synthetic antioxidants with the natural ones (green tea infusion and ascorbic acid), Principal Component Analysis and Minitab software version 17 was applied.

RESULTS AND DISCUSSION

The analysis of the relationship between the quantitative and qualitative parameters in the presence of synthetic antioxidants

Main Component Analysis (MCA) on the quantitative and qualitative parameters of the samples has been shown in figure 1. The relationship between the detected parameters in the current research based on their location has presented that peroxide index has negative relationship with water activity of the achieved products. Peroxide index is considered as an index of the quality of the fried products, therefore antioxidants have been added in the frying oil to reduce and control this parameter of the products. The negative relationship might be due to the effect of water activity on oxidation process controlling and as a result of oxygen outflow of the products and reductions in oxidative activity. Water activity has twin effects on the progress of oxidation reaction. With enhancement in the fluidity of the product, it might transmit the created free radicals and make better penetration in the products structure [24]; moreover it might prevent the reaction progress with creation of cross links between free radicals, as a result of it, the oxidation rate decreases. Furthermore water activity as a hydrogen donation agent, might decrease aggressive features. The obtained results presented that in the presence of synthetic antioxidants, the water activity decreases the oxidative reaction rates. Moreover peroxide index has shown positive relationship with the volume and different colour parameters of the surface as well as the colour parameters of the internal parts of the achieved products. The positive relationship of peroxide index with the volume of the product might be justified by the gluten network and as a result, its effects on the improvement of the network. On the other hand, as a result of oxidation process in colorant agents, the brightness of the products is affected by peroxide index. The colour is considered as one of the important parameters since it attracts the customers. Many parameters might affect on the colour. The most regular reactions destroying the colorants including Carotenoids, Anthocyanins and Chlorophylls are as the following: Maylard, enzymatic browning and oxidation reactions [25]. Therefore, oxidative activities might affect on the colour parameters of the obtained products. Further scientists [26, 27] proved and reported the similar results on the oxidation (peroxide index enhancement) and its effect on the brightness created by colorants reduction. Also the obtained results demonstrated that, the general acceptance has the positive relations with the firmness of the product. In other words, the evaluated sensory properties were affected by the products' texture properties.

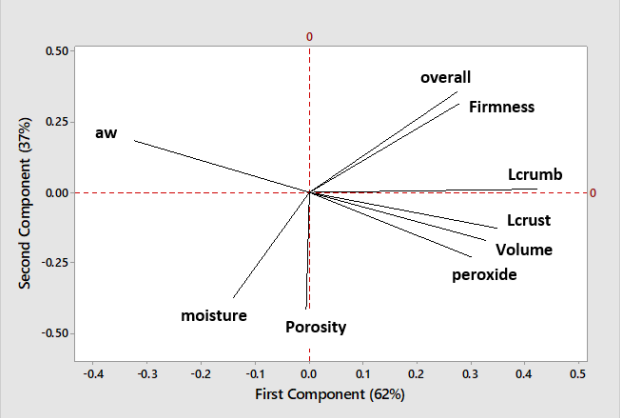

Fig. 1. Relationships Between Physicochemical Properties in the Control Sample

The analysis of the relationship among qualitative and quantitative properties of the products with the addition of green tea infusion

Figures 2, 3 and 4 respectively present the alterations in the detected parameters of the product with enhancement in green tea infusion. As shown in figure 2, in the presence of 100 ppm green tea infusion, the peroxide index showed negative relationship with the volume and moisture content of the product. On the other hand, the achieved results presented that, the moisture content and volume of the samples have shown positive relationship with each other. Moisture increases the volume of the samples with affecting on the inflation of the starch molecules. The Amylose and Amylopectin might create polymer that can make the achieved products' structure stronger. Therefore enhancements in the firmness of the products' structure might prevent of the outflow of the produced gas by yeasts. It should be noticed that, the ultra enhancement in the firmness (polymerized and crystallized Amylose-Amylopectin) of the product might not be acceptable for customers. Zolfaghari et al. 2013 reported that, frying due to creating thick surface of Doughnut and Slight shrinkage might prevent of the reduction of products' volume. Moisture content might with emitting out of environmental oxygen as well as alterations in reactions from oxidative deterioration to lipolysis could affect negatively on

peroxide index. Brightness parameters of the surface and internal parts of Doughnut, expressed positive relations with each other. This correlation between the abovementioned parameters might be due to the effect of green tea infusion in the concentration of 100 ppm on both of brightness parameters of surface and internal parts. The alterations between different parameters including porosity, firmness and general acceptance, were recorded positively. The relationship between the porosity and firmness on standard product's texture also indicated the similar effect of those with synthetic antioxidants and green tea infusion in the level of 100 ppm. Moreover the general acceptance presented negative relation with water activity. In other words, the addition of 100 ppm green tea infusion in Doughnut formulation reduced the general acceptance of the product with negative effect on water activity. The cause of this phenomenon most likely might be due to the effect of water activity on enzymatic browning reactions and as a result, it affects on the colour parameters of the products' surface.

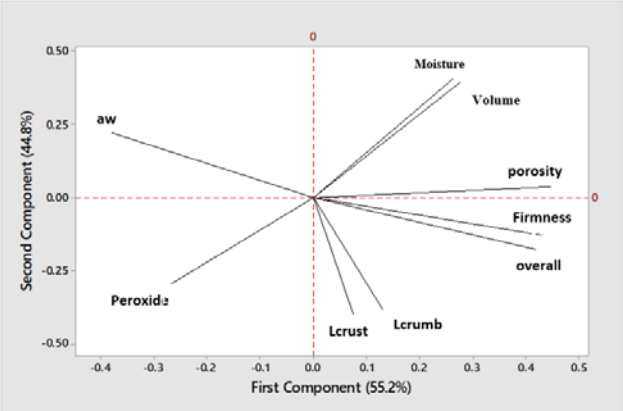

Fig. 2. The relationship between the physicochemical properties in the presence of 100 ppm of green tea extract

Figure 3 indicates the alterations between detected parameters of doughnut with enhancements in the level of green tea infusion up to 150 ppm in dough formulation. As it is observed, relationship between the peroxide index and firmness parameters is negative. It means that in samples containing 150 ppm green tea infusion, with enhancement in peroxide index, firmness value presented negative alterations. While the standard sample presented independent behaviour through alterations between the firmness and peroxide parameters. The cause of this behaviour of addition of green tea infusion in samples, might be justified by the oxidative activity of oil and its effects on retro gradation rate and the connections between Amylose-Amylopectin molecules in starch granules. Moreover the alterations between peroxide index with brightness parameter and volume showed considerable correlation. Tsong et al. (2010) [28] and Dogan et al. (2005) [29] reported that colour alterations during cooking process have affected by oxidation and as a result it affects on the pigments of green tea and polyphenols. On the other hand, further parameters including surface brightness and water activity presented positive alterations with each other. These alterations with sample's volume are negative. Furthermore the general acceptance presented independent relations with other detected parameters in the present study. In other words the effects of parameters in the level of 150 ppm infusion presented no considerable effects on general acceptance.

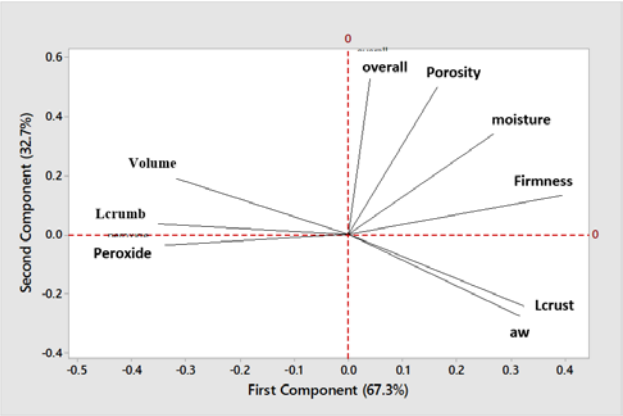

Fig. 3. The relationship between the physicochemical properties in the presence of 150 ppm of green tea extract

Figure 4, demonstrates the addition of 200 ppm green tea infusion and its effect on the detected parameters in the current study. As shown, the relationship between the peroxide index and firmness was positive. The effects of additional green tea infusion might be justified by the reduction in peroxide index compared to 165 ppm green tea infusion and as a result its tiny effect on the physicochemical properties of the product. Also such an alterations on the internal parts of Doughnut showed negative effects with the firmness and peroxide index of the products. The highest alterations in brightness parameter of Doughnut's surface and its internal parts' presented negative effects with moisture content. The negative effect of internal moisture content of Doughnut with the brightness parameters (In the presence of 200 ppm green tea infusion) might be justified by polyphenol oxidase enzyme presence in green tea infusion and the moisture content of the product [30]. The polyphenol oxidase enzyme activity might increase with a reduction in moisture content and as a result of it the brightness decreases.

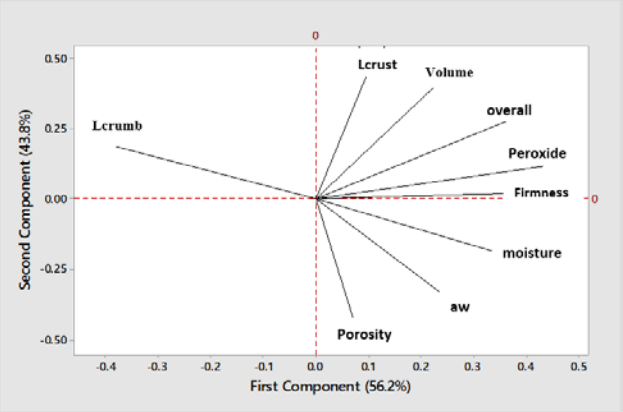

Fig. 4. The relationship between the physicochemical properties in the presence of 200 ppm of green tea extract

Analysis of the relationship between the qualitative and quantitative parameters of the product with the addition of ascorbic acid

The figures 5 to 7 respectively show the relationship between different detected Doughnut parameters and enhancements in ascorbic acid level. As shown in figure 5, the relationship between peroxide enzyme and brightness of Doughnut's surface is negative. The negative relationship in the presence of 50 ppm ascorbic acid might be justified by the oxidative activity of ascorbic acid and as a result the alterations of peroxide index in product. With creation of secondary compounds and their contact with the environmental oxygen in the surface of the product (Doughnut), the darkness of the product's surface increases. On the other hand the detected relationship between the peroxide index and general acceptance of the product, presenting the lowest desirability. These alterations are due to the acyl groups of non saturated triglycerides and further ingredients of non saturated oil that might create undesirable effects on sensory properties of the products such as odour and taste [31, 32]. Regarding the relationship between the peroxide index and alterations in samples' volume, direct and positive relationship was recorded. These alterations are relevant to oxidative activity on gluten network and as a result an enhancement in the resistance of the created network through cooking process. The same relation was observed in standards in the presence of synthetic antioxidants. The firmness of samples expressed positive relations with the porosity value. An increased porosity in samples, is relevant to creation of improved structure of gluten and as a result, its capability in maintenance of the released Co2 by yeasts. Therefore creation of networks with high resistance might lead to an enhanced firmness of the products. Ascorbic acid as one of the oxidants is used extensively in bakery industry. This additive with making disulfide connections might increase gluten resistance. Therefore due to this phenomenon, the retentively of the produced gas in cells and as a result the volume of the product increases [33]. Moreover Valentina and Bulter (2007) [34] reported the similar result and proved the considerable effect of ascorbic acid on the improvement of gluten network and texture of the products. The direct relationship was also detected between the water activity of Doughnut's internal parts and brightness. This phenomenon might be justified by the fluidity in product's texture and as a result its improvement on oxidation process and brightness in samples [24].

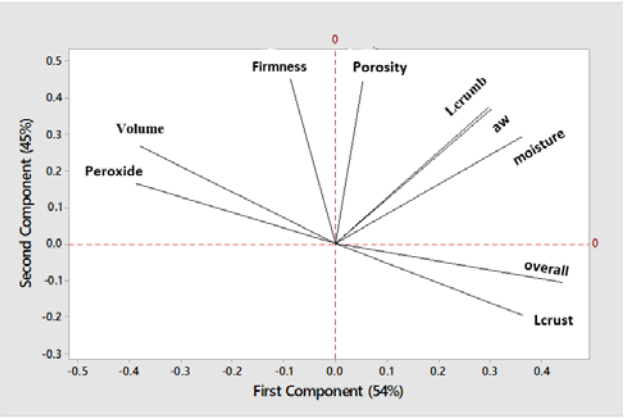

Fig. 5. The relationship between physicochemical properties in the presence of 50 ppm ascorbic acid

Figure 6 indicating the relationship between the detected Doughnut's parameters in the presence of 100 ppm ascorbic acid as an antioxidant agent in product. In the present condition (presence of ascorbic acid in the product), direct relationship was detected between water activity and peroxide index of the product. The relationships between these two parameters (water activity and peroxide index) have been detected positive with porosity and firmness parameters. Regarding the effect of water activity on peroxide index, it should be mentioned that, enhancement in water activity might improve fluidity and transmission of oxidants. Moreover, positive relationship between the surface brightness and moisture content was detected. Moisture content has the most considerable effect on the product's surface. The presence of ascorbic acid in products increases the moisture content of the product with creation connections between water molecules. Retro-gradation in Doughnuts' structure (like starch) is affected by moisture enhancement and as a result the surface properties are improved.

Based on the present relationship, it might be conveyed that the produced surface in the presence of 100 ppm ascorbic acid, might express higher moisture content and as a result higher brightness of the product was achieved.

In this regard Purlis and Salvadori (2009) [25] reported that the moisture maintenance ability during cooking process, might lead to the production of smooth surface, as a result of it the light reflex of the products' surface increases and the brightness of the produced product increases. Furthermore, the achieved results presented that the general acceptance is in the middle of moisture content and water activity, indicating the positive effect of these two parameters on the general acceptance of final products.

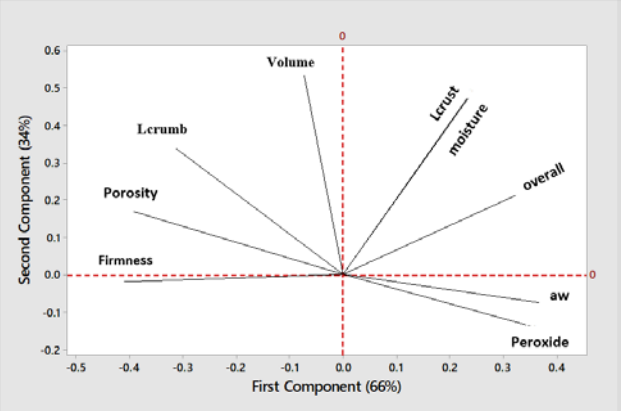

Fig. 6.The relationship between physicochemical properties in the presence of 100 ppm ascorbic acid

Figure 7 demonstrating the relationship between the selected parameters in the presence of 150 ppm ascorbic acid. Based on the observed relationships between the parameters, peroxide index in comparison to water activity is independent and in comparison to internal parts' brightness has negative relationship. The negative effect of moisture content of the product on peroxide index might be justified by enhancements in the fluidity of texture and the positive effect of ascorbic acid on reduction of the produced free radicals levels and its controlling impact on oxidative activity. Furthermore reduction in oxidative activity decreased the darkness of Doughnuts' internal parts. On the other hands, positive relationship between the firmness and peroxide index as well as negative effects between the products' volume and peroxide index were detected. The negative relationship between the firmness and samples' volume might be justified by reductions in Amylose-Amylopectin connection leading to reductions in firmness and enhancements in volume. Valentina and butler (2007)[34] and El-Hady and El-Samahy (1999)[36], presented that once ascorbic acid in the concentration ranged 100-200 ppm is used in bakery industry, the volume of the product increases and as a result of it, the firmness of the product decreases. The same researchers reported volume reduction and firmness enhancement of the product once ascorbic acid in the level of 200 ppm was applied in the formulation.

General acceptance showed positive relationship with the brightness of surface and internal parts as well as the volume and moisture contents of the products. Ascorbic acid in the level of 100 ppm increased general acceptance with affecting on oxidative parameters, colour and volume of the products and enhancement in water maintenance capacity of the product. Moreover presenting negative relationship between water activity and porosity of the product was observed. In cereal based products, the porosity depends on water activity of products and as a result with enhancement in water activity, the porosity decreases [37]. This phenomenon might be due to the addition of ascorbic acid in formulation of Doughnut of which an enhancement in water absorbance, leads to inflation in product's structure and as a result of it the porosity decreases.

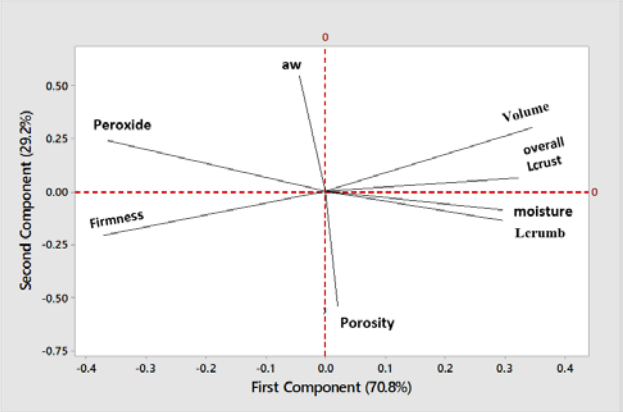

Fig. 7. The relationship between physicochemical properties in the presence of 100 ppm ascorbic acid

Analysis of the interaction between ascorbic acid and green tea infusion

Enhancement in ascorbic acid concentration in fixed surface of green tea infusion

In order to study the alterations between different Doughnut parameters and the interactive effects of additional ascorbic acid and green tea infusion in the level of 150 ppm in formulation, the level of ascorbic acid increased. Figure 8 demonstrating the relationship between qualitative and quantitative parameters of Doughnut in the presence of ascorbic acid in the level of 50 ppm. Based on the achieved results as presented in figure 3 (Green tea infusion) and figure 5 (ascorbic acid), it is shown that peroxide index has direct or positive relation with product's volume. While these two parameters (peroxide index and sample volume) presented negative relationship with the brightness of surface and general acceptance of the product. This phenomenon was observed when ascorbic acid in the level of 50 ppm and green tea infusion in the level of 150 ppm (figure 8) was applied in the formulation

of product. Furthermore once green tea infusion is applied lonely or in combination with ascorbic acid in the formulation, the porosity and moisture content parameters, presented the same behaviour in the final product. Thus it might be demonstrated that when green tea infusion in combination with ascorbic acid is applied, peroxide index, products' volume, brightness and general acceptance are considerably affected by ascorbic acid, and porosity value, moisture content and water activity are significantly affected by green tea infusion. The achieved result also demonstrated that there is no any interactive effect between green tea infusion with 150 ppm and ascorbic acid with 50 ppm levels.

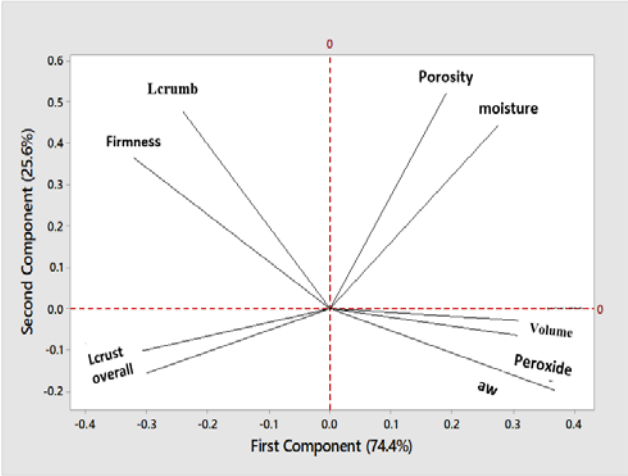

Fig. 8. The relationship between the physicochemical properties in the presence of 150 ppm green tea extract and 50 ppm ascorbic acid

Figure 9 presenting the relationship between Doughnut's parameters in the presence of 150 ppm green tea infusion and 100 ppm ascorbic acid. As observed as well, negative relationship between peroxide index and firmness of the product in the presence of green tea infusion was observed. This relationship indicating that there is no any interactive effect between ascorbic acid and green tea infusion as well as the synergistic effects between both parameters on the texture of the product. Regarding further parameters between green tea infusion and ascorbic acid, interactive relation was found.

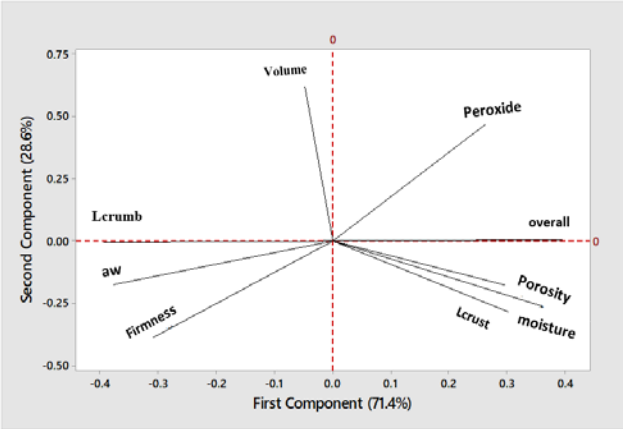

Fig. 9. The relationship between physicochemical properties in the presence of 150 ppm green tea extract and 100 ppm ascorbic acid

Figure 10 expressing the relation between Doughnut parameters in the presence of 150 ppm green tea infusion and 150 ppm ascorbic acid. As observed, in mixed environment of both antioxidants, only negative relationship between sample volume and brightness of the surface was detected. Revealing these properties might be due to the presence of colorant agents in the infusion and their effects on the colour of surface. In this regard, Tsong et al. (2010) [28] reported the similar results once green tea infusion as an antioxidant agent in the formulation of sponge cake was added, they also introduced the present colorants in green tea as agents of darkness and reduction of brightness of the produced samples. On the other hand, among further parameters, independent behaviour was observed in the presence of green tea infusion and ascorbic acid once the agents were applied individually, this phenomenon indicating improvement in interactive effects between both antioxidants in Doughnut oil.

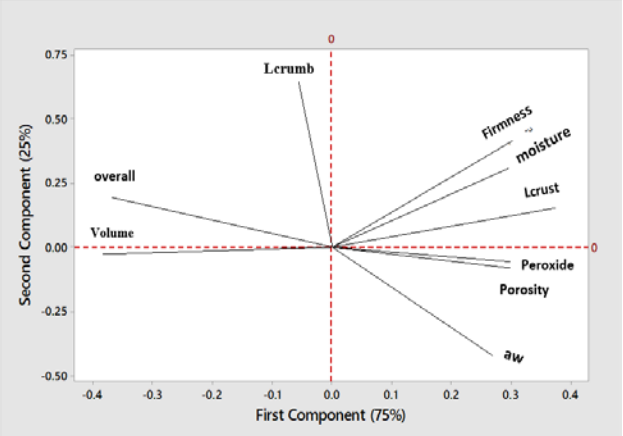

Fig. 10. The relationship between physicochemical properties in the presence of 150 ppm green tea extract and 150 ppm ascorbic acid

Moreover the achieved results demonstrated that, the interactive effects are observed in the presence of ascorbic acid over 50 ppm. In other words in the concentration equals to 50 ppm or less the interactive effects between both antioxidants (ascorbic acid and green tea infusion) was not found.

The current research studied the effect of the enhanced concentration of green tea infusion and its synergistic effect on ascorbic acid in the level of 100 ppm and the alterations between the qualitative and quantitative parameters of the produced Doughnut.

Figure 11 indicating the interactive effects of both antioxidants in the environment containing 100 ppm green tea infusion and 100 ppm ascorbic acid. The achieved results demonstrated that between the firmness and water activity in the presence of each antioxidant, negative relationship was found while the positive effect was detected between those two parameters once both antioxidants were used simultaneously in the formulation. Moreover further parameters expressed independent behaviour between parameters in the presence of both antioxidants in the formulation compared to when they are used individually. This phenomenon indicating the interactive effects between antioxidants and as a result their different behaviours on the product parameters.

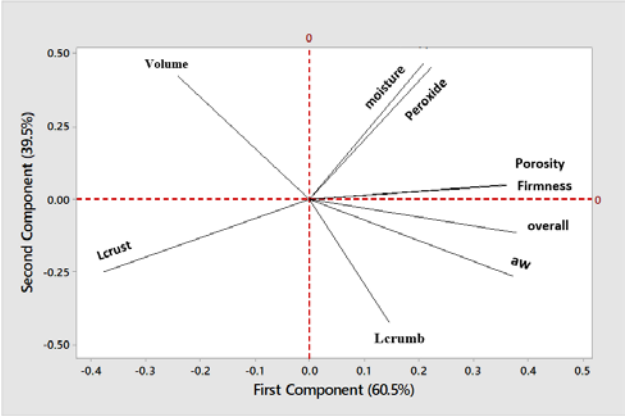

Fig. 11. The relationship between physicochemical properties in the presence of 100 ppm ascorbic acid and 100 ppm green tea extract

Figure 12 expresses the presence of 200 ppm green tea infusion and 100 ppm ascorbic acid in the formulation. As shown, independent relationship between the parameters exists when they are used together. Moreover regarding the first component space (green tea infusion) and second component space (ascorbic acid), it was shown that the behavior in combined state is similar to that the green tea infusion is used lonely in the formulation. This phenomenon expressing the predominant effects of green tea infusion compared to ascorbic acid in defining the relationship between the studied parameters. Most likely the cause might be due to the presence of phenolic compounds of green tea and their maintenance during frying process of Doughnut. In this regard Holtekjolen et al. (2008) [38] demonstrated that, phenolic compounds are resistant against high temperature and during cooking process are not destroyed and keep their antioxidant properties.

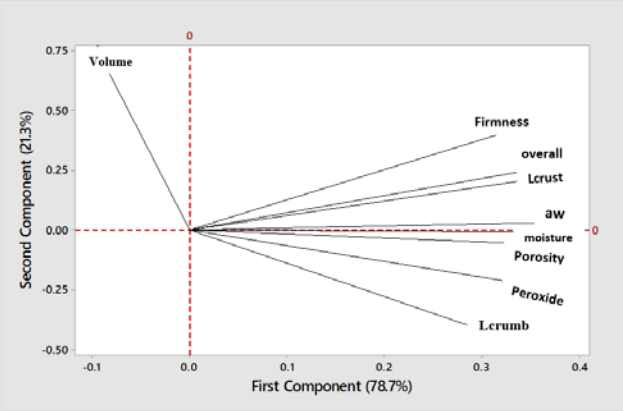

Fig. 12.The relationship between physicochemical properties in the presence of 100 ppm ascorbic acid and 200 ppm of green tea extract

CONCLUSION

Principal Component Analysis (MCA) approach expresses the alteration rate between different parameters. In the present research the relationship between different physicochemical and sensory properties of Doughnut with the use of Principal Component Analysis (PCA) has been studied. The determination of the applied alterations in samples based on the changes in the applied antioxidants and their levels has made, their effects on the products and as a result their controlling efficacy on the alterations in a desirable direction, understandable for customers and scientists. The achieved outcomes demonstrated that the created alterations as a result of added green tea infusion and ascorbic acid in different levels individually or combined in the formulation, affected considerably on peroxide index that this phenomenon might affect on other parameters. Furthermore the achieved results demonstrated the alteration direction on physicochemical and sensory properties of Doughnut in the presence of green tea infusion and ascorbic acid. Regarding the synergistic effects between both antioxidants, the obtained results demonstrated ascorbic acid's synergistic effect on green tea infusion in concentration over 50 ppm.

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