ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

Review Article

Kinetic Models on Quality Changes during Heat Blanching of Some Fruit and Vegetables

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Abstract: Blanching has been used as a thermal treatment in food processing especially as a pre-treatment of processes such as drying, freezing and canning of fruits and vegetables. Blanching treatment helps to remove microorganisms, lengthen the shelf life and enhance the colour, flavour and texture of fruits and vegetables. However, blanching may also affect the nutrients and characteristics of fruits and vegetables that contribute to the changes in their quality. . Thus, it is necessary to study the quality changes during heat blanching of fruits and vegetable in terms of characteristics, nutrients and properties of the fruits and vegetables. Kinetic modelling on the quality changes of fruits and vegetables is crucial for quality control during the heat blanching treatment. Kinetic modelling is also important to identify the optimum temperature and time needed to maintain the quality of fruits and vegetables after the heat blanching treatment. It is also useful to identify the kinetic trend of fruits and vegetables properties after the blanching process . In this paper, general aspects of the blanching process were discussed. Properties and methods to measure the quality changes during blanching were also highlighted. Kinetic models according to the properties and characteristics affected by the blanching treatment were also reviewed.

Keywords: Fruits and vegetables; blanching; thermal treatment; quality changes; kinetic modelling

Received: 13th March 2021

Received in revised form: 21st January 2022

Accepted: 21st January 2022

Available Online: 4th February 2022

Citation: Halim, A.A.A., Shamsudin, R., Ariffin, S.H,, *et al.* Kinetic models on quality changes during heat blanching of some fruit and vegetables. *Adv Agri Food Res J* 2022; 3(1): a0000265. https://doi.org/10.36877/aafrj.a0000265

1. Introduction

1.1 Function of Blanching as Thermal Treatment

Blanching is the heating of vegetables and fruits rapidly to a predetermined temperature and making the temperature constant where the standard duration is between 1 to less than 10 minutes (Xiao *et al.*, 2017). Then, the blanched products will be cooled rapidly or continue for the next processes such as drying, freezing, frying, and canning. The main reason for blanching as one of the critical food processing is to eliminate the spread of microorganisms that contributes to the short shelf life and deterioration of fruits and vegetables. According to Jabba (2014), the amount of yeast and mold decrease in carrots after blanching, where the process was incorporated with the combination of hot water and ultrasound treatment. Furthermore, blanching can improve the texture and flavour of the fruit and vegetables. Ding (2011) stated that to consume dabai fruit, it needs to be blanched in hot water with a temperature of about 50°C for the duration of 15 to 20 minutes to make the flesh softer and further improve the smooth-creamy texture and the rich flavour of the fruits and vegetable. As shown in Figure 1, the difference in physical appearance of the dabai fruit prior and after blanching can be observed. The texture of dabai fruit becomes smooth-creamy after blanching.

(a) **(b)**

Figure 1. Physical appearances of dabai fruit in (**a**) Unblanched form (**b**) Blanched form

Fernández (2006) also mentioned that blanching of potatoes before turning them into mashed potatoes enhanced their colour to desirable light-coloured and increased the thickness of the product. Blanching can help to destroy the enzymes that contribute to quality degradation such as off-flavours, undesirable smell, colour and texture (Xiao *et al.*, 2017). Based on the observation of frozen carrots by Kidmose and Martens (1999), it was stated that unblanched frozen carrot has a less desirable taste because of the freed fatty acids resulting from the esterase activity. Hence, blanching is one of the treatments to maintain the nutrient and quality of the fruit and vegetables as well as soften the texture.

1.2 Types of Blanching Method

Blanching could be done in many ways and the most common ones are the conventional hot water and steam blanching methods. With the advancement of technology, there were many more innovative methods of blanching such ass microwave and ohmic blanching methods. These methods use heat (thermal) as a food treatment where it involves heating the food rapidly at a preset temperature constantly in a specified duration usually within 1 to less than 10 minutes. (Xiao *et al.*, 2017). Table 1 lists the types of blanching with the conditions, advantages and limitations of the treatments.

Table 1. The advantages and limitations of different types of blanching methods. (Xiao *et al.*, 2017).

No	Types of blanching	Conditions	Advantages	Limitations
1.	Hot water blanching	Immersed in hot water at 70 to 100°C.	Simple to establish	Leaching and diffusion of nutrients from the food may happen
2.	Steam blanching	The usage of superheating steam as heating medium	Keep most amount of minerals and water soluble-components	Expensive
3.	Microwave blanching	The microwave energy was absorbed and converted into heat using dielectric heating effect.	Has volumetric heating, the heating rates is high and only need short processing times.	Non- uniform heating and difficult to control the temperature
4.	Ohmic blanching	Heat generated by using the electrodes	Short time, reduces leaching and keep the colour and texture of product.	Difficulty to control the temperature and corrosion of the electrodes.

2. Impacts of Blanching

Colour, texture and the bioactive compounds are most affected qualities in blanched fruits and vegetables. Texture and colour of fruits and vegetables are the most important attributes that the consumers look for as the result of the blanching process. Furthermore, the texture and colour attributes also can be affected by other parameters. Thus, these two attributes were classified as the main indicators for the measurement of quality of blanched fruits and vegetables.

2.1 Colour

Colour was greatly affected by the blanching treatment as the heat from the treatment destroyed the pigments which leads to the colour changing of the fruits and vegetables. Carotenoids and chlorophylls are the most identified pigments in fruits and vegetables . These pigments can be degraded by heat that resulting in undesirable colour. The colour was measured by using a colorimeter. According to Strecker *et al.*, (2010) using the CIE Lab colour space will be able to imitate the human visual perception where the measurements *L**, a*and b* were used. The CIE Lab colour spherical colour space with a vertical axis represents lightness (+*L**) to darkness (-*L**). The parameters *a** and *b** indicate the colour directions where +*a** is the red direction, -*a** is the green direction, +*b** is the yellow direction and -*b** is the blue direction. For example, Gonçalves *et al.*, (2007) recommended that phenolics contribute to the colour of the carrot and carotenoids were responsible for the orange colour of the carrot. Furthermore, changes in the green colour vegetables were related to the degradation of the chlorophylls where chlorophylls were converted to pheophytins and pyropheophytins (Cruz *et al.*, 2007). Moreover, according to Jaiswal *et al.* (2012), *L**, *a** and *b** degradations that cause the increase in the total colour difference in all the vegetables were due to the leaching of the pigments into the water during the blanching process. The changes in these vegetables colour were commonly due to the degree of blanching thermal treatment which causes an irreversible modification to the cellular tube. In addition, these colour changes may be related to the alteration of the light reflection from the cell surface. It is due to the replacement of the gases inside the intercellular spaces by the blanching medium (Bowers, 1992; Cruz *et al.*, 2007).

2.2 Texture

Texture is one of the important conditions that need to be considered to see the effect of blanching towards fruits and vegetables. It is because, blanching treatment will soften the tissues of the fruits and vegetables leading to changes in firmness, crispness and crunchiness and also the instrumental measurements that include cutting energy and maximum shear force (Powers *et al.*, 2004). A common enzyme that contributes to the changes of the texture of fruits and vegetables is pectin methyl esterase. Pectin methyl esterase helps to retain the firmness of the fruits and vegetables and inactivates due to the heating process during blanching. According to Xiao *et al.* (2017), the texture is often used as the indicator in the blanching process as it will determine the physical-chemical properties of the cell wall. It also indicates the impact to the texture of the products during blanching process. This is caused by the cell membrane disruption and changes in the integrity of the cell wall polymers. The firmness of the blanched fruit was used to quantify the changes in texture thermal degradation (Abu-Ghannam & Jaiswal, 2015). Moreover, during blanching, the texture might be affected by the increment in water absorption that changes the integrity of the cell wall too. This has been observed by Urga *et al.* (2006) where by the water absorption of the blanched seed increased significantly due to the change in its integrity of the seed coat.

Texture can be measured using the texture analyser where certain parameters which are related to the food product will be observed.

2.3 Bioactive Compounds

Every fruit and vegetable has bioactive compounds that are responsible for their nutrient contents. Some of the bioactive compounds in the fruits and vegetables that were affected to the blanching treatment were phenolic, anthocyanin, carotenoids, polyphenols and β-carotene Nutrient contents were looked upon as the important attributes of a product by the consumer for their consumption. The thermal process can result in the degradation of bioactive compounds in fruits and vegetables as it causes chemical and physical changes. Gonçalves *et al.* (2010) have proofed that the total phenolic content degrades as the blanching process was done on carrot because of the heat and leaching of phenolics into the blanching water. However, according to Ling *et al.* (2015), the bioactive compounds of some fruits or vegetables increases after the blanching treatment, thus the blanching treatment may enhance the nutrients in some fruits or vegetable. During the blanching treatment it can cause structural changes in plant tissues which improve in the extraction of bioactive compounds.

3. Kinetic Modelling of Quality Changes of Fruits and Vegetables Fruit

The nutrient losses due to thermal heat blanching can be predicted by using the spectrum of kinetics that includes reaction order, rate constant and activation energy. It is essential specifically when it comes to thermal processing such as blanching. (Nambi *et al.*, 2016). The kinetic modelling is essential in the blanching process to maximise the quality of the blanched fruits and vegetables; provided with the optimum blanching temperature and duration. Several models have been proposed to predict the colour, texture and bioactive compound changes.

3.1 Kinetic Models

Kinetic modelling of food quality changes in the thermal mechanism was performed by quantifying the quality attributes such as colour and texture variables. These two variables play significant roles during blanching where the heating period at a specified temperature was performed using temperature-dependent reaction rate constants where the order of reactions is determined (Ling *et al.*, 2015). Table 2 tabulated the list of kinetic models based on reaction order. The best kinetic model would be the one that fitted the data optimally; based on the selection of the reaction order model. The changes in food quality often follow the sequence starting from zero, first and second order kinetic models; respectively. However, the fractional conversion model which is based on the first kinetic model was suggested when the quality parameter varies from a start value until a residual value, which is continued.

Table 2. Kinetic models based on reaction order. (Ling *et al.*, 2015)

No	Kinetic models		Reaction order
1.	$P = P_0 - kt$	(1)	Zero order (n=0)
2.	$P = P_0 e^{-kt}$	(2)	First order (n=1)
3.	$\frac{P - P_{eq}}{P_0 - P_{eq}} = e^{-kt}$	(3)	First order (Fractional conversion)
3.	$\frac{1}{P} = kt + \frac{1}{P_0}$	(4)	Second order (n=2)

P_0 = initial value of the food quality attribute at t=0; eq =equilibrium value; t= blanching time; k= rate constant

To explain any temperature-dependent quality, Arrhenius equation is the essential equation where temperature plays the most important role. Arrhenius equation can describe the effect of the temperature *(T*) on the reaction rate constant (*k*) where the equation goes as stated in Equation 5:

$$k = k_0 e^{-\frac{Ea}{RT}} \quad (5)$$

where Ea refers to activation energy in the unit of J/mol, k_0 is the rate constant, *T* stands for the temperature in Kelvin and *R* is the ideal gas constant that equals to 8.314 J/mol.K. The Arrhenius equation can also be written in another form in Equation 6:

$$k = k_{ref} \exp\left[-\frac{Ea}{R}\left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right] \quad (6)$$

where k_{ref} stands for rate constant of the reference temperature (T_{ref}).

3.2 Common Kinetic Models Based on Quality Changes.

3.2.1 Texture

The common kinetic models proposed for the texture changes of fruit due to thermal blanching is either zero or the first model. The list of published data on the kinetics of texture degradation of some fruits and vegetables were listed in Table 3. Numerous studies were performed focusing on the kinetic models of the texture degradation due to the blanching treatment including the Irish York cabbage (Jaiswal *et al.*, 2012), pumpkin (Gonçalves *et al.*, 2007), carrot (Gonçalves *et al.*, 2010), broccoli (Gonçalves *et al.*, 2009), green beans ((Ruiz-ojeda & Peñas, 2013) and dabai fruit (Shamsudin *et al*., 2021). Most of the published studies indicated that the texture changes during blanching treatment follow the first-order degradation kinetics (Jaiswal *et al.*, 2012; Ruiz-ojeda & Peñas, 2013). Nevertheless, Gonçalves *et al.*, (2007) proposed the fractional conversion model while Gonçalves *et al.*, (2010) suggested using zero models for describing the textural changes of the vegetables.

The texture changes of the vegetables that were well fitted to the first order kinetic model were due to the less texture degradation at prolong blanching time. Meanwhile, for the vegetable textural degradation that fitted with fractional conversion order was greatly affected by blanching time and temperature.

Table 3. Published data on kinetics of texture degradation of some fruits and vegetables.

No	Texture parameter	Material	Blanching method	Reaction order	References
1.	Firmness	Irish York cabbage	Hot water	First order	(Jaiswal *et al.*, 2012)
2.	Firmness Energy	Pumpkin	Hot water	First order (Fractional conversion)	(Gonçalves *et al.*, 2007)
3.	Firmness Energy	Carrot	Hot water	First order (Fractional conversion)	(Gonçalves *et al.*, 2010)
4.	Maximum shear force	Broccoli	Hot water	Zero order	(Gonçalves *et al.*, 2009)
5.	Firmness	Green beans	Microwave	First order	(Ruiz-ojeda & Peñas, 2013)

3.2.2 Colour

Most of the published studies state that the changes of colour obey the zero or first order kinetic reactions. It is also reported that the usage of the fractional convectional model was applied to describe the trend changes of colour in fruits and vegetables. The list of published data on the kinetics of colour changes of some fruits and vegetables were listed in Table 4.

Table 4. Published data on kinetics of colour changes of some fruits and vegetables during blanching.

No	Color parameter	Material	Blanching method	Reaction order	References
1.	C^*	Irish York cabbage	Hot water	Zero order	(Jaiswal *et al.*, 2012)
2.	L^*, a^*, b^* and C^*	Pumpkin	Hot water	First order (Fractional conversion)	(Gonçalves *et al.*, 2007)
3.	L^*, a^*, and b^*	Carrot	Hot water	First order First order	(Gonçalves *et al.*, 2010)

No	Color parameter	Material	Blanching method	Reaction order	References
				(Fractional conversion)	
4.	L^*, a^*, C^* and ΔE	Mangosteen pericarp	Hot water	Zero order First order	(Ziabakhsh Deylami *et al.*, 2016)
5.	L^*, a^*, b^* and ΔE	Watercress	Thermal and thermosonication	First order (Fractional conversion)	(Cruz *et al.*, 2007)

3.2.3 Bioactive compounds

According to Ling *et al.* (2015), first order kinetic model is the most commonly used in studying the kinetics changes of the bioactive compounds of the fruits and vegetables. The list of published data on bioactive compounds of some fruits and vegetables were listed in Table 5.

Table 5. Published data on the kinetics of bioactive compounds of some fruits and vegetables during blanching.

No	Bioactive compounds	Material	Blanching method	Reaction order	References
1.	Phenolic content	Broccoli	Hot water	First order	(Inheiro *et al.*, 2009)
2.	Phenolic content	Carrot	Hot water	First order	(Gonçalves *et al.*, 2010)
3.	Antioxidant capacity	Irish York Cabbage	Hot water	First order	(Jaiswal *et al.*, 2012)
4.	Antioxidant capacity	Garlic	Steam blanching	First order	(Kinalski *et al.*, 2014)
5.	Carotenoids	Papaya puree	Hot oil-water	First order	(Arcia *et al.*, 2002)

4. Conclusions

In this article, a brief review of the function of blanching as thermal treatment is given. The different types of blanching technology are also reviewed in this article which focuses on the method, advantages and limitations of each technology. This paper also highlights the main attributes of fruits and vegetables that were affected by the blanching process which are texture, colour and bioactive compounds that reduce the quality of the fruits and vegetables. The common kinetic models that were used to estimate the changes rate of the quality parameters of various vegetables and fruits on the measured time- temperature of the blanching process also were also studied in this paper. In conclusion, the most influenced quality parameters to be studied on the effect of the blanching treatment are colour and firmness which influenced the product acceptability the most. The first, second, and fractional conversion kinetic orders were the suitable reaction orders for kinetic models to be applied for the blanching studies. Kinetic studies of the quality parameters of fruits and vegetables can help to optimise the quality of fruits and vegetables as the blanching process is commonly used for food processing

Funding: The authors would like to thank the Ministry of Higher Education of Malaysia, for providing financial support under the Fundamental Research Grants Scheme (FRGS) (Project Number: FRGS/1/2019/WAB01/UPM/02/30) and the Sarawak Biodiversity Centre for approved and issued the R&D permit.

Conflicts of Interest: The authors declare no conflict of interest, and also the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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