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Peeling of gingers as evaluated by image analysis techniques: A study for pickled ginger process

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Abstract: This paper applied chemical and enzymatic peeling techniques to enhance the efficiency of ginger peeling process. Gingers were peeled using different chemical and enzymatic peeling conditions before being washed by ginger washer/peeler. The efficiency of the peeling process was evaluated using image analysis techniques. It was found that the optimum condition for chemical peeling of gingers was soaking in NaOH solution (1 g/100 g water) at 80°C for 60 s. The yield obtained was 87.4% by weight. Image analysis showed that the average unpeeled area of gingers was 8.73%. It was found that commercially available fruit peeling enzymes had the potential to be used in ginger peeling. The best yield obtained from enzymatic peeling was 90.57% by weight. It also reduced the average unpeeled areas to 1.20%. Enzymatic peeling enhanced the efficiency of the peeling by removing the peels of the areas that could not be reached by chemical peeling. Pickled gingers produced from experimentally peeled gingers provided lower pH, higher protein content and darker color when compared to those made from hand peeled gingers.

Keywords: Ginger, pickled ginger, peeling, chemical peeling, enzymatic peeling, image analysis

Introduction

Peeling is an important step for processing of fruits and vegetables. It is currently conducted by mechanical, chemical, thermal (steam and freeze) and enzymatic methods (Toker and Bayindirli, 2003). The ideal peeling method aims to remove the peel with high efficiency and low peeling losses. Practically, each method of peeling has its own benefits and limitations depending on various factors (Emadi *et al*., 2007). Manual abrasive peeling could result in close to the ideal peeling (Somsen *et al.*, 2004; Arazuri *et al*., 2010). Mechanical method has the advantage of retaining edible portions of the produce fresh and damage-free. However, this method is not flexible and generating high losses (Emadi *et al*., 2007, 2008). Chemical peeling applies a hot solution of caustic soda in which the product is immersed for a certain period of time. Despite a concern in the rise for chemical cost and the associated disposal problems, it is commonly used for peeling of some vegetables such as tomatoes (Das and Barringer, 2006). Several authors have investigated the chemical peeling for various fruits and vegetables (Floros and Chinnan, 1990; Garrote *et al*., 1993; 1994; Barreiro *et al.*, 1995, 2007). Moreover, steam peeling is one of the most popular methods due to its high automation, precise control of time, temperature and pressure by modern process control devices. Thus, it minimizes peeling losses and reduces environmental pollution as compared to chemical peeling (Garrote *et al*., 1997, 2000). Recently, enzymatic peeling which is based on the treatment of fruits with corresponding glycohydrolase enzymes has been suggested (Pretel *et al.*, 1997). This method involves no harsh treatment, hence, the amount of broken segments and juice losses are much less than the conventional method and the peeled fruit has a better texture and appearance. Enzymatic peeling has been studied with focus on citrus fruits (Ben-Shalom *et al*., 1986; McArdle and Culver, 1994; Rouhana and Mannheim, 1994; Soffer and Mannheim, 1994; Pretel *et al*., 1997; Prakash *et al.*, 2001; Pretel *et al*., 2005). The others have investigated the potential of enzymatic peeling in some stone fruits (Toker and Bayindirli, 2003; Kaur *et al.*, 2009) and vegetables (Suutarinen *et al*., 2003).

Peeling of gingers is the important step for various ginger processes including pickled gingers. Gingers are irregular in shape and not in a spherical geometry. Therefore, the peeling process is a very tedious, time-consuming and labor intensive. Complex shapes of gingers also make mechanical peeling ineffective. There is currently limited work with regard to the peeling of gingers. This research investigated the peeling of gingers, with emphasis on pickled ginger process, using a combination of various peeling methods. The peeling efficiency was investigated by image analysis which currently has been proved to be the valuable tool (Srikaeo *et al*., 2006; Pallottino

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et al., 2010). The findings could help pickled ginger industry in process designs. It could also contribute to research on fruit and vegetable peelings especially the peeling of irregular shape fruits and vegetables in which better understandings are still in need.

Materials and Methods

Materials

Freshly harvested gingers with an average weight of 85 g/piece were obtained from Wang Thong Agri-products Co., Ltd. in Phitsanulok Province Thailand. Ginger washer/peeler is the lab-scale model and made locally with the capacity of 20 kg/batch (Fig. 1). Sodium hydroxide (AR grade) was obtained from Lab-Scan Asia Co., Ltd. Fruit processing enzymes which contained commercial grade of pectolytic enzymes (Brand A and B) were obtained from National Centre for Biotechnology Education, University of Reading, UK. According to the information provided from the supplier, Brand A is the mixture of pectolytic enzymes with the main enzyme is β-glucanase. The major enzymes in Brand B are pectintranseliminase, polygalacturonase and pectinesterase. They both exhibit optimum activity around pH 4.5 and at 50°C. The declared enzyme activities for Brand A and B are 100 FBG/g and 26,000 PG/mL, respectively. It should be noted that there is currently no standard for declaration of activity for commercial enzymes. Therefore, the declared units are different.

Table 1. Chemical peeling condition for each experimental treatment used in this study

Experimental treatment codes	NaOH concentration (g/100 g water)	Temperature (°C)	Time (s)
C1	1.0	70	60
C2	1.0	70	120
C3	1.0	80	60
C4	1.0	80	120
C5	1.5	70	60
C6	1.5	70	120
C7	1.5	80	60
C8	1.5	80	120

Table 2. Enzymatic peeling condition for each experimental treatment used in this study [a]

Experimental treatment codes	Enzyme types	Time (min)
E1	Brand A	50
E2	Brand A	60
E3	Brand B	50
E4	Brand B	60

[a]The concentration of enzyme used in this study was 1 g/100 g solution (for both enzymes) and soaking at 40°C, according to the literatures and supplier recommendations.

Figure 1. Lab-scale ginger washer/peeler: 1) motor, 2) water tank, 3) rolling vessel and 4) stainless steel grates

Peeling of gingers

Fresh gingers (10 kg of total weight or approximately 120 pieces) were subject to chemical peeling using different conditions (Table 1) before being washed using tap water by the washer/peeler (Fig. 1) for 1 hr. The washer contains about 50 L of water for each batch and rotates at 48 rpm. Gingers which have been peeled using the optimum condition from chemical peeling were subject to enzymatic peeling with different enzyme conditions (Table 2). Peeled gingers were washed in the same way as described for chemical peeling. The peeling experiment was conducted in triplicate. The letter "C" was used as experimental treatment code for chemical peeling (Table 1) while the letter "E" was used for enzymatic peeling (Table 2). The conditions employed for both chemical and enzymatic peelings as shown in Table 1 and Table 2 were based on the literatures and/or suggested by the enzyme suppliers.

Peeling yields and quality examinations

The yield was expressed as the weight remained after peeling. The color of peeled gingers were measured in CIE $L^*a^*b^*$ (Minolta, CR-10). The texture of enzymatic peeled gingers was determined by puncture strength test (TA-XT2 Texture Analyzer) using 1 mm-diameter needle probe at the speed of 2 mm/s until the probe penetrated 5 mm into the sample. To minimize errors, 10 samples were randomly selected from each experiment for color and texture analysis. At least 5 spots for each sample were measured.

Image analysis for unpeeled areas

Total 25 samples were randomly selected from each experimental treatment for analysis. Pictures of peeled gingers were taken using a digital camera at 3,888 x 2,592 pixels at the same position and distance for all samples. The image analysis software, ImageJ (National Institutes of Health, US), was used. The method was developed based on the procedures described previously (Zhou *et al*., 2004; Sheffield, 2007; Remirez *et al*., 2009). Briefly, the images were converted to grayscale and the unpeeled areas were isolated using thresholding. Fig. 2 shows the example of image adjusting. The unpeeled areas or dark spots in the images were quantified as the percentages of total areas in pixels.

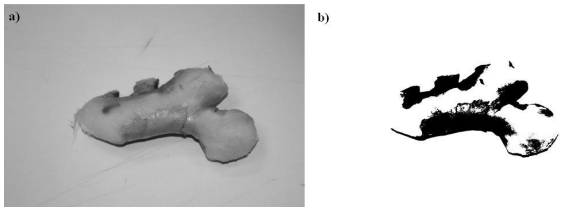

Figure 2. Example of ginger pictures prepared for image analysis, a) before thresholding, and b) after thresholding (the dark spots represent as unpeel areas)

Pickled gingers

Pickled gingers were produced from gingers which have been peeled using the best condition from chemical and enzymatic peeling methods described previously. Hand peeled gingers were also used to produce pickled gingers for comparison. To avoid the effects from other factors, pickled conditions were controlled to be the same for both types of gingers. Peeled gingers (2 kg or about 25 pieces) were placed in an opaque plastic jar that contained sufficient brine solution specially prepared for pickled gingers. The brine solutions were kindly provided by Wang Thong Agri-products Co., Ltd. The pickled process took 3 months under room temperature. Pickled gingers were analysed for their properties. Color ($L^*a^*b^*$) was examined using the same method as described earlier. The components and microbiological properties (total plate count and yeast and mold count) were evaluated for both types of pickled gingers using standard methods (AOAC, 2000). Experiments were conducted in triplicate.

Statistical analysis

Completely randomized design (CRD) was used for experimental design. Analysis of variance (ANOVA) and test of significance were performed using SPSS® ver. 17 with confidence level of 95%.

Results and Discussions

Chemical peeling

Table 3 shows the peeling yield, unpeeled area and color of the samples from each experimental treatment. Statistical analysis suggested that all factors significantly affected ($p \leq 0.05$) the response variables. It was found that C3 gave the maximum yield. However, in terms of color, C4, C6 and C8 were preferred as they provided high L^* and positive b^* values, indicating the brightness and yellowness of peeled gingers. Unpeeled areas, as assessed by image analysis, of C1, C3 and C6 were found to be minimal. Therefore, in this experiment, it can be concluded that C3 (NaOH 1 g/100 g water, 80°C and 60 s) was the optimum condition as it used less chemicals and provided good results. There are currently no published data about chemical peeling of gingers. Previous works have investigated the use of chemical peelings in tomatoes (Floros and Chinnin, 1990; Garcia and Barrett, 2006), potatoes and asparaguses (Garrote *et al*., 1993, 1994, 1997), hazelnuts (Kaleoglu *et al*., 2004) and in some stone fruits (Guldas, 2003; Toker and Bayindirli, 2003). This paper shows the potential of applying chemical peeling in an irregular shape vegetable such as gingers. Moreover, the optimum condition for caustic peeling of gingers in this study is milder than those reported previously with other fruits and vegetables. This could be influenced by the difference in morphologic characteristics, skin adherence and its thickness including the degree of union between the peel segments. The mild condition used for ginger peeling could provide benefits in terms of cost saving and environmental friendly process. It could also reduce strange tastes in the products caused by chemical peeling.

Enzymatic peeling

Table 4 shows the results of enzymatic peeling (refers to the conditions in Table 2) which aimed to enhance the chemical peeling. Statistical analysis found that all factors significantly affected the responses ($p \leq 0.05$). Considering all quality characteristics, although E3 gave the best color result (the highest L^*), E2 was chosen in this study as it provided the maximum yield, minimum unpeeled areas and firm texture (high puncture force). Therefore, it can be concluded in this study that using peeling enzyme (Brand A) for 60 min can enhance the peeling of gingers after being peeled by chemical peeling as described earlier. The unpeeled area reduced from 8.73% to 1.20% (refers Table 3-4).

Researches on enzymatic peeling have been focused on citrus fruits (Ben-Shalom *et al*., 1986; Rouhana and Mannheim, 1994; Soffer and Mannheim, 1994; Pretel *et al*., 1997, 2007). A few published works have investigated the use of enzymatic peeling in stone fruits (Toker and Bayindirli, 2003; Kaur *et al*., 2009) and in some vegetables (Suutarinen *et al*., 2003). Recently, Pagán *et al*. (2010) studied enzymatic peeling in grapefruits. Many factors influence the effectiveness of enzymatic peeling. These include types of enzymes, concentrations and application conditions (Rouhana and Mannheim, 1994; Soffer and Mannheim, 1994; Prakash *et al*., 2001), cuts and shapes, vacuum infusion conditions (Baker and Wicker, 1996; Pretel *et al*., 1997; Prakash *et al*., 2001) and fruit and vegetable skin adherence and its thickness (McArdle and Culver, 1994).

This study has investigated the use of two commercial pectolytic enzymes. Although, both enzymes mainly contained pectolytic enzymes but they provided different effectiveness when applied to ginger peeling. In this study, Brand A was found to be suitable for gingers. Toker and Bayindirli (2003) have reported the use of the same enzyme in apricots, nectarines and peaches.

Pickled gingers

The properties of pickled gingers produced from

Table 3. Yield, unpeeled area (as evaluated by image analysis techniques) and color of chemically peeled gingers from each experimental treatment [a,b]

Experimental treatment codes	Yield (% by weight)	Unpeel area (%)	Color		
			L*	a*	b*
C1	$81.63^{f} \pm 0.34$	$8.70^{e} \pm 0.32$	$59.87^{e} \pm 0.28$	$5.35^{a} \pm 0.28$	$29.90^{de} \pm 0.52$
C2	$84.45^{d} \pm 0.46$	$9.51^{d} \pm 0.45$	$61.30^{d} \pm 0.36$	$3.23^{b} \pm 0.36$	$29.33^{e} \pm 0.52$
C3	$87.40^{a} \pm 0.12$	$8.73^{e} \pm 0.09$	$62.11^{c} \pm 0.36$	$2.78^{bc} \pm 0.36$	$32.51^{b} \pm 0.34$
C4	$86.35^{b} \pm 0.27$	$10.15^{c} \pm 0.40$	$64.54^{a} \pm 0.12$	$2.22^{cd} \pm 0.12$	$33.33^{a} \pm 0.38$
C5	$81.07^{g} \pm 0.17$	$10.67^{c} \pm 0.29$	$62.09^{c} \pm 0.21$	$2.13^{d} \pm 0.21$	$33.42^{a} \pm 0.17$
C6	$83.27^{e} \pm 0.23$	$8.60^{e} \pm 0.42$	$63.22^{b} \pm 0.39$	$2.55^{cd} \pm 0.39$	$30.53^{cd} \pm 0.57$
C7	$85.48^{c} \pm 0.14$	$13.55^{b} \pm 0.44$	$62.13^{c} \pm 0.39$	$2.67^{cd} \pm 0.39$	$25.87^{f} \pm 0.27$
C8	$85.50^{c} \pm 0.16$	$14.43^{a} \pm 0.17$	$62.70^{bc} \pm 0.22$	$2.65^{cd} \pm 0.22$	$30.97^{c} \pm 0.09$

[a]Values are means ± standard deviations.
[b]Figures with the different letters in a column indicate that they are significantly different ($p \leq 0.05$) and "ns" means they are not significant ($p > 0.05$). These apply to all tables where they appear.

Table 4. Yield, unpeeled area (as evaluated by image analysis techniques), puncture strength and color of enzymatically peeled gingers from each experimental treatment

Experimental treatment codes	Yield (% by weight)	Unpeel area (%)	Puncture strength (g.F)	Color		
				L*	a*	b*
E1	$87.12^{c} \pm 0.15$	$1.60^{b} \pm 0.08$	$1{,}028^{b} \pm 2.22$	$61.27^{b} \pm 0.05$	$3.08^{a} \pm 0.02$	$27.75^{b} \pm 0.11$
E2	$90.57^{a} \pm 0.05$	$1.20^{d} \pm 0.08$	$1{,}165^{a} \pm 1.62$	$60.71^{d} \pm 0.05$	$2.93^{b} \pm 0.01$	$26.63^{c} \pm 0.08$
E3	$88.30^{b} \pm 0.15$	$1.88^{a} \pm 0.03$	$939^{c} \pm 2.10$	$63.33^{a} \pm 0.03$	$2.12^{d} \pm 0.04$	$27.78^{b} \pm 0.13$
E4	$88.19^{b} \pm 0.18$	$1.39^{c} \pm 0.09$	$856^{d} \pm 3.15$	$60.86^{c} \pm 0.08$	$2.44^{c} \pm 0.09$	$28.41^{a} \pm 0.14$

Table 5. Physical properties (pH and color), components (moisture, protein, fat, crude fibre, ash) and microbiological properties (total plate count and yeast and mold) of pickled gingers produced from hand peeled and experimentally peeled gingers

Samples	pH	Moisture [ns] (g/100 g dry sample)	Protein (g/100 g dry sample)	Fat [ns] (g/100 g dry sample)	Crude fiber [ns] (g/100 g dry sample)	Ash [ns] (g/100 g dry sample)
Hand peeled	$2.64^{a} \pm 0.00$	96.24 ± 0.05	$0.49^{b} \pm 0.08$	0.36 ± 0.02	0.54 ± 0.02	0.71 ± 0.02
Experimentally peeled	$2.31^{b} \pm 0.00$	95.60 ± 0.07	$0.52^{a} \pm 0.01$	0.32 ± 0.02	0.55 ± 0.02	0.75 ± 0.02
	Color (L*)	Color (a*)	Color (b*) [ns]	Total plate count [ns] (log CFU/g sample)	Yeast and mold [ns] (log CFU/g sample)	
Hand peeled	$56.53^{a} \pm 0.07$	$3.96^{b} \pm 0.07$	14.60 ± 0.07	2.86 ± 0.02	1.73 ± 0.04	
Experimentally peeled	$46.34^{b} \pm 0.12$	$14.02^{a} \pm 0.19$	17.94 ± 0.05	2.95 ± 0.02	1.74 ± 0.03	

hand and chemically/enzymatically peeled gingers are shown in Table 5. Chemical and enzymatic peelings used in this experiment induced several changes in pickled gingers when compared to hand peeling. The color of hand peeled gingers was brighter than those from experimentally peeled gingers as indicated by L^* values. The darker color found in experimentally peeled gingers was influenced by the redness as indicated by higher a^* values. Red pickled gingers are preferred by the industry. The red color which is developed during the pickling process may be from the reactions between the brine and some pigments. Chemicals and enzymes used during peeling process could cause the release of pigments from ginger cell walls and enhance the red color in the final product. In addition, they could also damage ginger cell walls and allow more brine solution to penetrate into the cells during pickling, resulting in the difference of pH and protein content. However, the other properties including microbiological properties were not significantly different ($p > 0.05$). Further studies on the effects of chemical and enzymatic peelings on gingers are required.

Conclusions

Chemical peeling can be applied to the peeling of gingers with milder conditions than that applied to other fruits and vegetables. This promotes the cost saving and environmental friendly process for chemical peeling of gingers. Commercial peeling enzymes can also be used to enhance the effectiveness of ginger peeling, particularly the unpeeled areas that cannot be reached by chemical peeling. Notably those different brands which contained the same major enzymes provided different effectiveness. Chemical and enzymatic peeling caused some changes in pickled gingers when compared to those produced from hand peeling. They also enhanced the red color of pickle gingers. Further studies about ginger peelings are required as gingers are complex in shape and this makes peeling difficult and labor intensive. The development of effective peeling for gingers could be useful for the industry. In addition, this paper demonstrated that image analysis technique was the useful tool for analysis of effectiveness of peeling process.

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References

AOAC. 2000. Official Methods of Analysis of AOAC International. 17th edn. AOAC International.

Arazuri, S., Jaren, C., Correa, P. C. and Arana, I. 2010.

Influence of the peeling process on pepper quality. Journal of Food Agriculture and Environment 8: 44-48.

Baker, R. A. and Wicker, L. 1996. Current and potential applications of enzyme infusion in the food industry. Trends in Food Science and Technology 7: 279–284.

Barreiro, J. A., Caraballo, V. and Sandoval, A. J. 1995. Mathematical model for the chemical peeling of spherical foods. Journal of Food Engineering 25: 483-496.

Barreiro, J. A., Sandoval, A. J., Rivas, D. and Rinaldi, R. 2007. Application of a mathematical model for chemical peeling of peaches (*Prunnus persica* L.) variety Amarillo Jarillo. LWT-Food Science and Technology 40: 574-578.

Ben-Shalom, N., Levi, A. and Pinto, R. 1986. Pectolytic enzyme studies for peeling of grapefruit segment membrane. Journal of Food Science 51: 421–423.

Das, D. J. and Barringer, S. A. 2006. Potassium hydroxide replacement for lye (sodium hydroxide) in tomato peeling. Journal of Food Processing and Preservation 30: 15-19.

Emadi, B., Abbaspour-Fard, M. H. and Yarlagadda, P. K. D. V. 2008. Mechanical peeling of pumpkins. Part 1: Using an abrasive-cutter brush. Journal of Food Engineering 89: 448-452.

Emadi, B., Kosse, V. and Yarlagadda, P. K. D. V. 2007. Abrasive peeling of pumpkin. Journal of Food Engineering 79: 647-656.

Floros, J. D. and Chinnan, M. S. 1990. Diffusion phenomena during chemical (NaOH) peeling of tomatoes. Journal of Food Science 55: 552-553.

Garcia, E. and Barrett, D.M. 2006. Peelability and yield of processing totatoes by steam or lye. Journal of Food Processing and Preservation 30: 3-14.

Garrote, R. L., Coutaz, V. R., Luna, J. A., Silva, E. R. and Bertone, R. A. 1993. Optimizing processing conditions for chemical peeling of potatoes using response surface methodology. Journal of Food Science 58: 821-826.

Garrote, R. L., Coutaz, V. R., Silva, E. R. and Bertone, R. A. 1994. Determining process conditions for chemical peeling of asparagus. Lebensmittel-Wissenschaft und-Technologie 27: 19-22.

Garrote, R. L., Silva, E. R., Bertone, R. A. and Avalle, A. 1997. Effect of time and number of cycles on yield and peeling quality of steam peeled potatoes and asparagus. Lebensmittel-Wissenschaft und-Technologie 30: 448-451.

Garrote, R. L., Silva, E. R. and Bertone, R. A. 2000. Effect of thermal treatment on steam peeled potatoes. Journal of Food Engineering 45: 67-76.

Guldas, M. 2003. Peeling and the physical and chemical properties of kiwi fruit. Journal of Food Processing and Preservation 27: 271-284.

Kaleoglu, M., Bayindirli, L. and Bayindirli, A. 2004. Lye peeling of 'Tombul' hazelnuts and effect of peeling on quality. Food and Bioproducts Processing 82: 201-206.

Kaur, S., Sarkar, B. C., Sharma, H. K. and Singh, C. 2009. Optimization of enzymatic hydrolysis pretreatment conditions for enhanced juice recovery from guava fruit using response surface methodology. Food and Bioprocess Technology 2: 96-100.

McArdle, R. N. and Culver, C. A. 1994. Enzyme infusion: A developing technology. Food Technology 11: 85–89.

Pagán, A., Conde, J., Ibarz, A. and Pagán, J. 2010. Effluent content from albedo degradation and kinetics at different temperatures in the enzymatic peeling of grapefruits. Food and Bioproducts Processing 88: 77-82.

Pallottino, F., Menesatti, P., Costa, C., Paglia, G., De Salvador, F. R. and Lolletti, D. 2010. Image analysis techniques for automated hazelnut peeling determination. Food and Bioprocess Technology 3: 155-159.

Prakash, S., Singhal, R. S. and Kulkarni, P. R. 2001. Enzymic peeling of Indian grapefruit (*Citrus paradisi*). Journal of the Science of Food and Agriculture 81: 1440–1442.

Pretel, M. T., Botella, M. A., Amoro, A., Zapata, P. J. and Serrano, M. 2007. Optimization of vacuum infusion and incubation time for enzymatic peeling of 'Thomson' and 'Mollar' oranges. LWT-Food Science and Technology 40: 12-20.

Pretel, M. T., Lozano, P., Riquelme, F. and Romojaro, F. 1997. Pectic enzymes in fresh fruit processing: Optimization of enzymic peeling of oranges. Process Biochemistry 32: 43–49.

Pretel, M. T., Amoros, A., Botella, M. A., Serrano, M. and Romojaro, F. 2005. Study of albedo and carpelar membrane degradation for further application in enzymatic peeling of citrus fruits. Journal of the Science of Food and Agriculture 85: 86-90.

Remirez, C., Germain, J. C. and Aguilera, J. M. 2009. Image analysis of representative food structures: application of the bootstrap method. Journal of Food Science 74: R65-R72.

Rouhana, A. and Mannheim, C. H. 1994. Optimization of enzymatic peeling of grapefruit. Lebensmittel-Wissenschaft und Technologie 27: 103–107.

Sheffield, J. B. 2007. ImageJ, a useful tool for biological image processing and analysis. Microscopy and Microanalysis 13: 200-201.

Soffer, T. and Mannheim, C. H. 1994. Optimization of enzymatic peeling of oranges and pomelo. Lebensmittel-Wissenschaft und-Technologie 27: 245–248.

Somsen, D., Capelle, A. and Tramper, J. 2004. Manufacturing of par-fried French-fries. Part 2: Modeling yield efficiency of peeling. Journal of Food Engineering 61: 199-207.

Srikaeo, K., Furst, J. E., Ashton, J. F. and Hosken, R. W. 2006. Microstructural changes of starch in cooked wheat grains as affected by cooking temperatures and times. LWT - Food Science and Technology 39: 528-533.

Suutarinen, M., Mustranta, A., Autio, K., Salmenkallio-Marttila, M., Ahvenainen, R. and Buchert, J. 2003. The potential of enzymatic peeling of vegetables.

Journal of the Science of Food and Agriculture 83: 1556-1564.

Toker, I. and Bayindirli, A. 2003. Enzymatic peeling of apricots, nectarines and peaches. Lebensmittel-Wissenschaft und-Technologie 36: 215-221.

Zhou, T., Harrison, A. D., McKellar, R., Youg, J. C., Odumeru, J., Piyasena, P., Lu, X., Mercer, D. G. and Karr, S. 2004. Determination of acceptability and shelf life of ready-to-use lettuce by digital image analysis. Food Research International 37: 875-881.