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# Peeling of tough skinned fruits and vegetables: A review

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**Abstract**
Peeling is the preliminary and main stage of post-harvest processing of fruits and vegetables. The quality of processed fruits and vegetables is highly dependent on the peeling stage. Poor peeling management leads to expensive finished products due to high peeling losses and low quality of finished produce. Peeling methods fall into four main groups: mechanical, thermal, enzymatic and chemical peeling. A review on different methods of peeling has been made in order to compare peeling methods on variety of products. The review has been arranged on the basis of the technique used along with examples of the latest works of interest.

**Keywords:** Peeling, mechanical, thermal, chemical, properties

## Introduction
Peeling is performed before further process it as fruit or vegetable based products During the processing of any fruit or vegetables based products, it is important to minimize the loss of yield while retaining the quality of the products through ideal peeling methods (Toker *et al*., 2003; Srikaeo *et al*., 2011; Rock *et al*., 2012) [57, 53, 46]. The peeling process involves a series of biochemical (chemical disintegration towards fruit skin), thermal (high temperature) and physical mechanisms (separation of the skin from biochemical and thermal effects) to adequately loosen and remove the skin of the fruits (Garcia and Barrett, 2006; Srikaeo *et al*., 2011) [20, 53]. Various peeling methods have been utilized including the use of hand/manual or mechanical, steam or hot, lye or chemical, and enzymes (Rock *et al*., 2012) [46]. However, high cost of labor and large amount of water are required for washing stage which has caused severe damage to the environment (Fellows, 2000; Wongsa-Ngasri, 2004; Das *et al*., 2006; Rock *et al*., 2011; Li, 2012) [16, 63, 9, 46, 34].

## Manual Peeling
Manual peeling can be performed using stationary or rotatory hand peelers or knives against the surface of fruits and vegetables. Fresh-cut fruit and vegetables with good microbiological quality can be obtained by this method. reported that knife peeling caused less wounding in comparison to abrasion peeling in carrots (Somsen *et al*., 2004; Arazuri *et al*., 2010: Rock *et al*., 2011) [1, 52, 46]. This can result lower microbial contamination after processing. However, despite of good results obtained by manual peeling, this method is limited to small scale processing and is laborious and requires more time (Emadi *et al*., 2007; 2008) [14, 15].

## Chemical peeling
### Lye Peeling
Lye peeling is one of the oldest methods used in the food industry. This method is used mainly for peeling fruits and vegetables. The lye peeling have been used extensively in peaches, tomato, kiwi and potato (Barreiro *et al*. 2007; Garcia and Barrett 2006b; Gómez-López *et al*. 2014) [2, 21, 23]. It involves the immersion of a product in alkaline solution at high temperatures (90–100 °C) (Di Matteo *et al*. 2012) [12]. In lye peeling, the lye solution dissolves the pectic and hemicellulosic material in the cell walls by cleaving the α-(1 → 4) bond between the individual galacturonic acid units. The removal of the pectin weakens the network of cellulose microfibrils and released the skin by collapsing the skin. (Barreiro *et al*. 2007) [2]. The alkaline solution used in lye peeling process is NaOH or KOH but NaOH is preferred as KOH is

generally expensive than NaOH (Das and Barringer 2006) [11]. Peeling time and peeling quality depends on the concentration of alkaline solution (Fellows, 2000; Kaleoglu *et al*., 2004; Garcia *et al*., 2002) [16, 31, 19]. The chemical–physical parameters in unpeeled and peeled samples did not show any differences in texture, sugar, protein and a-tocopherol contents while significant changes were observed in colour and total fat (Pagán *et al*., 2005 and 2010) [38, 37], Di Matteo *et al*. 2012) [12].

**Enzymatic Peeling**

Enzymatic peeling consists of treatment with a high-activity enzymatic solution containing polysaccharide hydrolytic enzymes, especially pectinases, cellulases, and hemicellulases since pectin, cellulose and hemicellulose are the polysaccharides most responsible for the adherence of the peel to the fruit ((Toker and Bayindirli, 2003, Suutarinen *et al*. 2003) [57, 54]. In enzymatic peeling, peeling efficiency depends on temperature, time and the ratio between peel mass and the enzyme solution volume ratio (Pagán *et al*. 2010a and 2010b) [36, 37]. The main advantages of enzymatic peeling are its ability to produce good quality product, requirement of the reduced heat treatment and production of low industrial waste.

**Thermal Peeling**

Thermal peeling as well as chemical peeling is used for thick-skinned vegetables. This method can be performed by wet heat (steam) or dry heat (flame, infrared, hot gases). Floros and Chinnan (1988a) [17] reported that the widespread application of steam peeling is due to its high level of automation, precise control of time, temperature and pressure by electronic devices to minimize peeling losses, and due to the reduced environmental pollution as compared to chemical peeling. This method of peeling - especially dry heat - causes a cauterizing of the surface, wound areas, and small pieces of charred skin, which if not removed, give a poor appearance to vegetables, especially canned ones (Weaver *et al*., 1980) [62]. Different types of thermal peeling are described below with reference to related works of interest. Different types of thermal peeling are described below with reference to related works of interest.

**Steam peeling**

Steam peeling is most popular among modern methods of peeling due to its widespread application, high automation, precise control of time, temperature and pressure; and reduced environmental pollution as compared to chemical peeling (Garrote *et al*. 2000) [22]. The steam peeling has advantages as increased production capacity and improved appearance of the product (Floros and Chinnan (1988b) [18]. Steam peeling has been explained as a combination of two phenomena. First it builds up internal pressure due to high temperature which causes mechanical failure of the cell, and secondly it affects the tissue resulting the loss of rigidity and reduced turgor pressure, melting and breakdown or disorganization of the cell wall substances, such has pectin and polysaccharides (Garrote *et al*. 2000) [22]. The vegetables are introduced in batches into a pressure vessel with steam (1,500 kPa) which rotates at a speed of 4–6 rpm. The rotation allows the vegetable surface to be treated by steam.

**Flame or dry heat peeling**

Flame or dry heat peeling consists of a conveyor belt that carries and rotates the vegetables through a furnace heated to 1,000 °C. The outer 'paper shell' and root hairs are burned off, and the charred skin is removed by high-pressure water sprays. Average product losses are usually 9%. Dry peeling is better than wet peeling in reducing microbial populations and preserving ascorbic acid content.

**Infrared Peeling**

I R heating technique is a novel dry-peeling method for peeling fruits and vegetables since it does not require any heating medium, such as lye, water, or steam (Li *et al*. 2014) [34]. IR dry-peeling resulted in lower peeling loss (8.3%–13.2% vs. 12.9%–15.8%), thinner thickness of peeled-off skin (0.39–0.91 mm vs. 0.38–1.06 mm), and slightly firmer texture of peeled products (10.30–19.72 N vs. 9.42–13.73 N). The method also ensured color and texture characteristics of the peeled products.

**Thermal blast peeling**

The vegetables and fruits are placed in a closed and elevated pressure vessel heated by infrared heat from the vessel wall and conductive heat from the superheated steam atmosphere. The heat treatment leads to an increased plasticity of the skin tissues caused by drying which will decrease the resistance of peel against rupture when steam flows under the skin. This stage is too short for heat to penetrate to the edible portion and the pressure is reduced to atmospheric pressure by instantly opening the vessel.

Harris and Smith (1986) [26] tested this method for Alfagold pumpkin under 343.33 °C within 45 minutes and got 89.4 per cent yield by weight. The process was able to reduce peeling losses from 28% to about 11% for saturated steam and thermal blast peeling respectively.

**Freeze-thaw**

Brown *et al*. (1970), Thomas *et al*. (1976), Goud (1983), and Woodroof and Luh (1988) [6, 55, 24, 64] attempted to eliminate the use of caustic solutions in the peeling of tomatoes by the use of the freeze-thaw method. In this method tomatoes are immersed in liquid nitrogen for 5-15 seconds, and then thawed in warm water at 66 ºC for 30 seconds to loosen the peel. The loss was about 5-7% but this method was not effective on immature yellow and green shoulder tissues. It was mentioned that the method is applicable for peaches as well.

**Vapour explosion (vacuum peeling)**

Drooge *et al*. (1999) [13] tested the vapour explosion method for removing the skins of fruits and vegetables by explosive vaporization of the moisture under the skin of fruits and vegetables. They placed the vegetable in a peeling vessel, and the pressure in the vessel was rapidly reduced (below atmospheric pressure), leading to explosive vaporization of the moisture. Drooge *et al*. 1999 suggested that it is possible to reduce the air pressure and to cool the vegetable before the vapour explosion. Kliamow *et al*. (1977) [32] called this method vacuum peeling. They applied vacuum at 600-700 mm Hg to tear the peel off tomatoes. They reported high peeling efficiency, retention of high fruit quality and low energy consumption as well as cost for this method.

**Mechanical Peeling**

Mechanical peeling includes different types of process that interact directly with skin and then removes the skin. Common commercial mechanical peelers are abrasive devices, drums, rollers, knives and milling cutters

(Shirmohammadi *et al.* 2012) [50]. Mechanical peelers can provide high quality fresh final products and they are environmental friendly and nontoxic. The method is associated material loss or peeling loss due to irregular weight, size and shape of produce, variation in the texture of skin/peel, rind and flesh and low flexibility of the machine. Thus, the products are loaded with unwanted mechanical loads (compression, impact, shearing and vibration) which results in bruising of the fruits.

**Table 1:** Different peeling methods and related research made.

| Method | Fruit/ vegetable | Conclusion | Researchers |
|---|---|---|---|
| Lye Peeling | Kiwifruit | NaOH concentration above 20% resulted in softening of skin | Gómez-López *et al*. 2014 [16]. |
| | Kiwifruit | Boiling solution of NaOH at 2.5% inhibited the enzymatic browning | Caceres *et al*. 2012 [7]; Di Matteo *et al*. (2012) [12], (Shi *et al*., 2000; Das *et al*., 2006; Kaleoglu *et al*., 2004) [49, 11, 31]. |
| | Potato | NaOH at 20% process temperature 72 ºC and time 7 minutes resulted in best peeling quality. | Garrote *et al*. (2000) [22]; Barreiro *et al*. 2007 [2]; Di Matteo *et al*. 2012 [12]; Das and Barringer 2006 [11]. |
| | Sweet potato | 30 minute pre-soak in naoh at 78-83 ºC resulted in best peeling efficiency | Walter *et al*. (1982) [61]; Pretel *et al*., 2008 [45]; Rock *et al*., 2012 [46]. |
| Enzymatic Peeling | Oranges | enzyme concentration of enzyme peeling be 1 ml L −1, optimum temperature 35–40 °C and pH range of 3.5–4.5 | Pretel *et al*. (2008) [45]; Pagán *et al*. 2010a [36], (Pagán *et al*., 2005 [38]; Pagán *et al*., 2010b [37], Pretel *et al*. (1998) [42], Pretel *et al*. (2005) [40]; Pretel *et al*. (2007) [41]. |
| | Citrus fruits | 1% pectinase solution at 40 °C for 15–40 min | Barrios *et al*. 2014 [3]; Toker and Bayindirli, 2003 [57]. Ben-Shalom *et al*., 1986 [5]; Rouhana and Mannheim, 1994 [47]; Soffer and Mannheim, 1996 [51]; Pretel *et al*., 1997 [43]; Pretel *et al*., 2001 [44]. |
| | Persimmon fruit | Bacterial and fungal counts of enzymatic peeling was least and quality parameters such as color index, pH and texture were unaffected in enzymatic treated product. | Murakami *et al*. (2012) [35], Toker and Bayindirli (2003) [57], Srikaeo *et al*. (2011) [53]. |
| | Apricot, nectarines, and peaches | better texture and appearance for product after enzymatic peeling because of fewer amounts of broken segments and juice losses | Janser (1996) [30]; Toker and Bayindirli (2003) [57]. |
| | Grapes | Vacuum infusion by immersion in an enzyme bath for 12 min followed by hand-peeling resulted in easy peeling. | Prakash *et al*. (2001) [39]. |
| Thermal Peeling | Tomatoes | steam at temperatures and flow rates of 425 to 480 ºC and 12-15 lb steam per $ft^2$ min respectively | Weaver *et al*. (1980) [62]. |
| | Pumpkin and apples | caustic and steam peeling methods superheated steam at 100 psig (7kg/$cm^2$) at mean inlet temperatures of 371 ºC Peeled yields in excess of 95% | Kunz (1978) [33]. |
| | Pimiento peppers | Constant temperature of 215º C and steam pressure of480 KPa. Each cycle was 10 seconds long (except the last which was 5 seconds). Steam was supplied and pressure built_up for the first 5 seconds. | Floros and Chinnan (1988a) [17]. |

However, it is still preferred among the current methods as it can keep edible portions of products fresh and harmless. The main factors affecting the peeling process are mechanical and physical properties of fruit and vegetable tissues, such as skin thickness, firmness, toughness, variety, rupture force, cutting force, maximum shearing force, shear strength, tensile strength and rupture stress (Shirmohammadi *et al*. 2012) [50]. The study of the physical and mechanical properties can improve the efficiency of peeling equipment i.e peelers.Many attempts have been made to develop optimized process to reduce the material loss (Grotte *et al*. (2001); Jackman and Stanley (1994); Voisey *et al*. (1970); Thompson *et al*. (1992); Jackman and Stanley (1992); Voisey and Lyall, 1965a; Voisey and Lyall, 1965b; Holt 1970; Voisey *et al*., 1970; Behnasawy *et al*., 2004; Rybczynski and Dobrzanski, 1994. Clevenger and Hamann, 1968; Thompson *et al*., 1992) [25, 28, 60, 56, 29, 58, 59, 27, 60, 4, 48, 8, 56].

Other approaches aimed to minimize the material loss in mechanical peeling of fresh fruits and vegetables is the development of computational models to simulate tissue damage. These models show potential of improving designs and selecting optimum conditions. Modeling can provide critical analysis by understanding the deformation during peeling process (Shirmohammadi *et al*. 2011) [50]. Modelling of mechanical peeling of fruits and vegetables will enhance efficiency and quality and can help to reduce material loss. Another significant advantage of models is the possibility of improving the life of tools by reducing wear (Emadi et al., 2007; Shirmohammadi *et al*. 2011) [15, 50].

## Conclusions

Except for manual abrasive peeling which results in close to the ideal peeling, other current peeling methods cause high waste of flesh (unexpected losses). But, manual peeling leads to more consumption of time and labour. Mechanical, chemical, and thermal (steam and freeze) are conventional peeling methods of fruits and vegetables. These methods use mechanical devices, caustic solutions, and heat to peel produce respectively. Each method has its benefits and limitations depending on the technique used. Mechanical methods can be preferred because of some certain advantages such as low damage to the flesh and enhanced freshness of peeled produce, low environmental pollution, and possibility of utilization of byproducts of the fruit.

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