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## Literary Review

- Microbial cross-contamination refers to the transfer, direct or indirect, of microorganisms (bacteria, virus, parasites, or fungi) from a contaminated item to a non-contaminated one (Minnesota Department of Health, 2007). In food, cross contamination of foodborne pathogens is a major concern since it increases the health risk for humans due to the intake of contaminated food. Otherwise, cross-contamination of foodborne pathogens from inert surfaces to foods is well documented (Kusumaningrum et al., 2003; Lin et al., 2006; Wilks et al., 2006; De Candia et al., 2015; Erickson et al., 2015).

- The adhesion and persistence of microorganisms to the surfaces can spread pathogens and spoilage microorganisms to foods, influencing their shelf-life and safety (Barnes et al., 1999; Bae et al., 2012). Several studies have showed the ability of microorganisms to attach to all the surfaces commonly found in the food processing environment, such as stainless steel, polystyrene, rubber, glass, wood and so on (Czechowski, 1990; Mafu et al., 1990; Krysinski et al., 1992; Suárez et al., 1992; Barnes et al., 1999; Siroli et al., 2014). Additionally, if microorganisms remain on a given surface for a relatively long time, they can multiply and, eventually, form biofilms (Uhlich et al., 2006).

- On the other hand, fresh produce have been associated in several outbreaks caused by E. coli O157:H7, Salmonella spp. and L. monocytogenes (Alegre et al., 2010; Scallan et al., 2011; Oliveira et al., 2012; Siroli et al., 2014). According to EFSA (2013), these products are involved in more than 5% of food borne illness in Europe. Also the USA Centre for Disease Control and Prevention (CDC) clearly showed the fresh produce as a source of contamination leading to food borne illnesses. In fact, pathogens, eventually introduced during the production chain, may remain until the product consumption due to the lacking of treatments able to eradicate the microbial cells. The interruption of cold chain during distribution, sale and home storage determine rapid deterioration of these products due to the growth of spoilage microorganisms present on fruit and vegetable. To increase the limited shelf-life of fresh produce the tendency is to pack unripe fruit and vegetable characterized by lower sensory features compared to ripe fruits.

- The literature data on the contamination levels of packaging materials are few and fragmented. However, they demonstrated that packaging materials can be contaminated by spoilage and pathogenic microorganisms (Suominen et al., 1997). The cell loads normally detected for mesophylic aerobic bacteria ranged between 103 and 106 cfu/cm2 for packages of recycled materials and between 102 and 105 cfu/cm2 for products based on virgin fibers (Suominen et al., 1997).

- The few literature data show that spore-forming bacteria (belonging to the genera Bacillus, Geobacillus, Alicyclobacillus, and Clostridium) and molds (belonging mainly to the species Aspergillus niger, A. cinnamomeus, and Cladosporium herbarum) prevail on packaging microbiota. They are widespread microorganisms, resistant to adverse environmental conditions and endowed with high spoilage potential (Binderup et al., 2002; Turtoi and Nicolau, 2007). However, also yeast and other spoilage bacteria can be present on packaging materials. To avoid and/or minimize this issue, the use of appropriate packaging is essential, since it acts as a barrier that can protect fresh food from contamination (Campos et al., 2014).

- However, although the Regulation (EC) No 852/2004 on materials and articles intended to come into contact with food stipulates that “the packaging must not be a source of food contamination,” understanding the real contribution of the packaging material in product contamination is not very simple due to the impossibility to establish “a priori”

the level of the naturally occurring fruit and packaging microflora. In addition, the microbial survival, growth or death on the packaging materials, and consequently their role in cross contamination of packed fruits, are affected by environmental conditions, including storage temperature, relative humidity and nutrient availability (Siroli et al., 2014; De Candia et al., 2015; Erickson et al., 2015). Also the growth potential of the microorganisms on fruit surface is affected by the intrinsic features of fruit species and variety (i.e., specific surface features, acidity, sugar content and so on), by the ripening and by the presence of wounds and exudates (Heaton and Jones, 2008).

- The attractiveness of fresh produces for consumers is determined also by organoleptic factors like appearance, firmness, taste and perceived health benefits as well as by safety and shelf-life of the product (Malmendal et al., 2011; Cuthbertson et al., 2012; Santucci et al., 2015).

- The fruit considered in this research (peach), being a living organism with high metabolic activity, is subjected to a rapid quality decreases after harvest due mainly to ethylene production. This causes several negative effects including senescence, accelerated quality loss, reduced nutrient composition, increased fruit pathogen susceptibility, physiological disorders in fruit and vegetables, and consequently the growth potential of microorganisms present on fruit surfaces (Martínez-Romero et al., 2007; Liu et al., 2015).

- Microbiological Testing of Fresh Produce – United Fresh White Paper

- Average APC #'s – Bacteriological quality of some readhy to eat vegetables as retailed and consumed in Sabon-gari, Zaria, Nigeria (Abdullahi, I.O and Abdulkareem, S

- Shelf Life of Fresh-Cut Fruits and Vegetables
  - The shelf life (i.e., the length of time that corresponds to a tolerable loss in quality of a processed food and other perishable items) of fresh-cut fruits and vegetables ranges from 1 to 35 days depending on types of shelf life (such as marketing shelf life, food safety shelf life, sensory shelf life, or microbiological shelf life) (M. Barth et al, 2013)
  - The average shelf lives of fresh-cut fruits and vegetables are typically 10-14 days (Cantwell & Suslow, 2002)

- The microorganisms that exist on the surfaces of raw, whole produce appear to be the major source of microbial contamination and consequent spoilage of fresh-cut fruits and vegetables (Sapers, Miller, Jantschke, and Mattrazzo (2001) reported that, compared with good surface sanitation practices, no decontamination treatment or an ineffective antimicrobial treatment on whole cantaloupe resulted in premature microbiological spoilage of fresh cut cantaloupe.
  - Robbs et al. (1996) – determined that the most common bacteria on raw celery plants, including fluorescent *Pseudomonasi* spp. And *Aeromonas* spp., were also the most common bacteria on cut celery products.
  - Boyette, Ritchie, Carballo, Blankenship, and Sanders (1993) reported that the microbial decay of fresh-cut lettuce is largelyl due to the growth of microorganisms originating from preharvest environments.
  - Delaquis, Stewart, Toivonen, and Moyles (1999) determined that the types of microorganisms found on shredded lettuce were highly associated with the microorganisms detected on lettuce before shredding.
  - Several studies (Magnusson, King, & Torok, 1990; Geeson, Churey, & Splittstoesser, 1990; Torok & King, 1991) have revealed that yeast species identified on fresh-cut produce can also be isolated from raw materials prior to processing
  - Garg, Churey, and Splittstoesser (1990) concluded that peel is the major source of microbial contaminants on carrots sticks
  - Several outbreaks of salmonellosis that were associated with cut cantaloupe and watermelon have resulted from *Salmonella* present on the rind contaminated in the field or packinghouse (Harris et al., 2003)
  - Inoculation of *Listeria monocytogenes* and *Salmonella* on the surface of entire cantaloupes resulted in the contamination to fresh-cut pieces during cutting (Ukuku & Sapers, 2001, Ukuku & Fett, 2002)

- These results indicate that the bacteria on the surface of whole produce are the same as those on fresh-cut produce and can contaminate finished product through processing

- Raw materials can contribute to contamination of produce products during cultivation, harvesting, packaging, and shipping, and there are no definite decontamination steps during processing. It is no surprise that a variety of microbial populations are present.
  - Goepfert (1980) reported that mesophilic aerobic bacterial populations on vegetables sampled at processing plants ranged from 4.6 (carrots) to 7.5 (peas) $\log_{10}$ CFU/g fresh weight.

- The mesophilic aerobic bacterial counts ranged from 4 to 6 $\log_{10}$ CFU/g fresh weight on finished cut vegetables and from 2 to 5 $\log_{10}$ CFU/g fresh weight on finished cut fruits, depending on the commodities, seasons of the year, and growing regions (Zhuang et al., 2003)
- The mesophilic aerobic bacterial counts on bagged salads from the retail market ranged from 4.0 to 9.0 $\log_{10}$ CFU/g (Heard, 2000)

- Many types of microorganisms can be found on a cut fruit or vegetable, including Gram-negative bacteria, Gram-positive bacteria, fungi (yeasts and molds). The type of fresh-cut commodity and the pH of fresh-cut products are the two primary intrinsic factors that determine the microbiological spoilage profile of fresh-cut products.
  - Regulation (EC) No 852/2004 on materials and articles intended to come into contact with food stipulates that "the packaging must not be a source of food contamination,"
  - In fact France and Germany microbiological specifications for mesophilic aerobic bacterial populations or aerobic plate counts (APC) of salad vegetables at production (fresh) are $5x10^6$ CFU/g, for separating good quality from marginally acceptable quality. And at use by date are $5x10^7$ CFU/g (Francis, Thomas, & O'Beirne, 1999; Lund, 1993)
  - Debevere (1996) proposed $10^8$ CFU/g of aerobic psychrotrophic bacteria, $10^5$ CFU/g of yeast, and $10^7$ CFU/g for lactic acid bacteria as the limiting criteria for ready-to-eat vegetables.
  - The Spanish legal limit (RD 3484/2000, 2001) for microbial populations on minimally fresh-processed fruit for safe consumption are 7, 5, and 3 $\log_{10}$ CFU/g for aerobic bacteria, yeasts, and molds, respectively.

- Regardless of raw material quality, GMPs, processing conditions, antimicrobial treatments, types of antibacterial packaging, temperature abuse shortens the shelf life of fresh-cut produce.(M. Barth et. Al 2013)
  - Temperature is one of the most impactful factors affecting the quality and microbiological characteristics of produce (M. Barth et. Al 2013

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