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Health risk for children and adults consuming apples with pesticide residue

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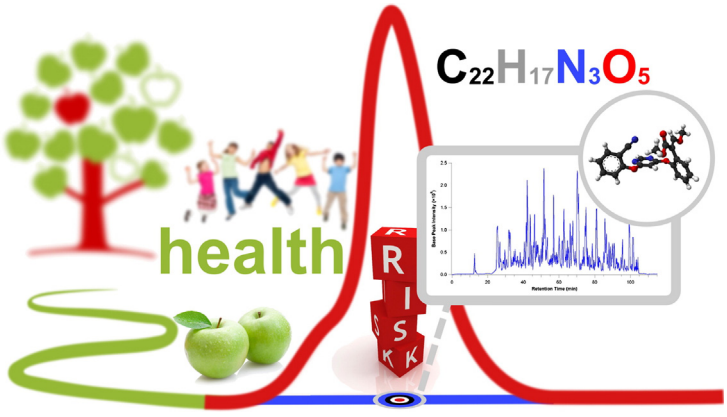
HIGHLIGHTS

- Over 60% of apple samples contain pesticide residues.
- Thirty four pesticides were detected, the most frequently detected were fungicides.
- Insecticides were detected above MRL more often.
- Samples with multiple residues (up to 7) were noted.
- The estimated risk of acute exposure was highest for flusilazole and tebuconazole.

GRAPHICAL ABSTRACT



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ABSTRACT

The presence of pesticide residues in apples raises serious health concerns, especially when the fresh fruits are consumed by children, particularly vulnerable to the pesticide hazards. This study demonstrates the results from nine years of investigation (2005–2013) of 696 samples of Polish apples for 182 pesticides using gas and liquid chromatography and spectrophotometric techniques. Only 33.5% of the samples did not contain residues above the limit of detection. In 66.5% of the samples, 34 pesticides were detected, of which maximum residue level (MRL) was exceeded in 3%. Multiple residues were present in 35% of the samples with two to six pesticides, and one sample contained seven compounds. A study of the health risk for children, adults and the general population consuming apples with these pesticides was performed. The pesticide residue data have been combined with the consumption of apples in the 97.5 percentile and the mean diet. A deterministic model was used to assess the chronic and acute exposures that are based on the average and high concentrations of residues. Additionally, the "worst-case scenario" and "optimistic case scenario" were used to assess the chronic risk. In certain cases, the total dietary pesticide intake calculated from the residue levels observed in apples exceeds the toxicological criteria. Children were the group most exposed to the pesticides, and the greatest short-term hazard stemmed from flusilazole at 624%, dimethoate at 312%, tebuconazole at 173%, and chlorpyrifos methyl and captan with 104% Acute Reference Dose (ARfD) each. In the cumulative chronic exposure, among the 17 groups of compounds studied, organophosphate insecticides constituted 99% acceptable daily intake (ADI). The results indicate that the occurrence of pesticide residues in apples could not be considered a serious public

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health problem. Nevertheless, an investigation into continuous monitoring and tighter regulation of pesticide residues is recommended.

1. Introduction

The health benefits associated with the regular consumption of fruit have been reported extensively over the last several decades. Epidemiological studies have shown that the consumption of apples has been associated with health benefits (Eberhardt et al., 2000). Apples are rich in flavonoids, polyphenols, vitamins, and minerals and contain many useful phytochemicals. The procyanidins epicatechin and catechin have strong antioxidant activity and have been found to inhibit low-density lipoprotein oxidation in vitro (Aprikian et al., 2001; da Silva Porto et al., 2003; Hyson et al., 2000;) and increase high-density lipoproteins, lowering the risk of type 2 diabetes (Cooper et al., 2012). Scientific evidence indicates that a diet rich in apples can decrease the risk of chronic diseases (Boyer and Liu, 2004; Davis et al., 2006; Yoon and Liu, 2007) and can induce weight loss in middle-aged overweight women (de Oliveira et al., 2003). Apples are one of the very few individual foods with the capacity to reduce cancer risk (Arts et al., 2001; Feskanich et al., 2000; Le Marchand et al., 2000).

It was found that women ingesting apples had a 13–22% decrease in cardiovascular disease risk (CDR) (Sesso et al., 2003) and that a reduced risk of death from CDR existed for men (Hertog et al., 1993). Another study (He and Liu, 2008) indicated that flavonoid-rich apples are one of three foods (along with red wine and pears) that decrease the risk of mortality for both coronary heart and CDR among post-menopausal women. Whole apples were found to protect against asthma as well as against bronchial hyperreactivity due to their anti-inflammatory and antioxidant properties (Shaheen et al., 2001; Woods et al., 2003). Apples contain high levels of antioxidants that reduce the risk of many neurodegenerative diseases, such as Alzheimer's and Parkinson's, counteract the ageing process, and may help to maintain brain performance (Rogers et al., 2004; Wu et al., 2004).

Prevention is a more effective strategy than treatment of chronic diseases. Fruits that contain significant amounts of bioactive components may provide desirable health benefits beyond basic nutrition and play an important role in the prevention of chronic diseases. However, apples must not contain toxic substances above defined safe limits.

Pesticides are commonly used in apple production (Sauphanor et al., 2009; Simon et al., 2011; Rawn et al., 2008; Pennel, 2006; Eurostat, 2002) to control phytophages or pests that may damage crops during production, storage or transport (Ticha et al., 2008). Pesticides allow growers to increase the amount of usable apples from each tree at the time of harvest. Pesticides may also improve the quality and shelf-life of certain foods. Pesticides have been linked to a wide range of human health hazards, ranging from short-term impacts such as headaches and nausea to chronic impacts such as cancer, reproductive harm, and endocrine disruption (Baldi et al., 2001; Benbrook, 1996; Rivas et al., 2007). Chronic health effects may occur years after even minimal exposure to pesticides in the environment, or in food and water, and pesticides can cause many types of cancer in humans (Alexander et al., 2012; Rusiecki et al., 2006). Several of the most prevalent forms include leukaemia, non-Hodgkin's lymphoma, and brain, bone, breast, ovarian, prostate, testicular and liver cancers (Cantor et al., 1992). A study reported that children who live in homes where their parents use pesticides are twice as likely to develop brain cancer as those that live in residences in which no pesticides are used (Bradman et al., 2007; CDC, 2002). There is also mounting evidence that exposure to pesticides disrupts the endocrine system (Mnif et al., 2011), the reproductive system, and embryonic development. Endocrine disruption can cause infertility and a variety of birth defects and developmental defects in offspring, including hormonal imbalances and incomplete sexual development, impaired brain development, behavioural disorders, and many others (Alavanja et al., 2004).

Children are particularly susceptible to the hazards associated with pesticide use (Bradman et al., 2007; Dalvie et al., 2014). They also represent a specific sub-population among the consumer population. The toxicity of pesticides in infants and children may differ quantitatively and qualitatively from that in adults. There is now considerable scientific evidence that the human brain is not fully formed until the age of 12, and childhood exposure to some of the most common pesticides may greatly impact the development of the central nervous system. Children have more skin surface for their size than adults, absorb proportionally greater amounts of many substances through their lungs and intestinal tracts, and take in more air, food and water per body weight than adults (Garry et al., 2002). The immune system, nervous system, and detoxifying mechanisms of children have not developed completely, leaving them less capable of resisting the introduction of toxic pesticides into their systems (CDC, 2002). Researchers have found that pesticide exposure can induce a poisoning response linked to asthma (Hoppin et al., 2008). The combination of likely increased exposure to pesticides and lack of bodily development for combating the toxic effects of pesticides means that children are suffering disproportionately from their impacts. Considering the multitude of risks associated with pesticide intake by infants, the European Union set a strict restriction for pesticides in infant food (EC, 2009).

The goal of this study was to assess the presence of pesticide residues in apples produced and consumed in Poland and those exported to countries of the European Union and Russian Federation, as well as to evaluate the health effect of detected residues on various consumer age groups with the utilisation of cluster diet models.

2. Material and methods

2.1. Samples

The 696 samples of apples (Table 1) from the north-eastern and central Poland were collected over a nine-year period (Fig. 1) (from 2005 to 2013) during official inspections from producers supplying apples to the domestic and European markets as well as from exporters to the Russian Federation.

2.2. Chemicals and reagents

All reagents used were of residue analysis grade. Acetone, acetonitrile, dichloromethan, diethyl ether and n-hexane for pesticide residue analysis were provided by J.T. Baker (Deventer, Holland), along with Florisil (60–100 mesh) and silica gel activated for 8 h at 600 °C. Anhydrous sodium sulphate and celite were purchased from Fluka (Seelze-Hannover, Germany). ChemElut cartridge containing diatomaceous earth was obtained from J.T. Baker (USA).

Table 1
Number of tested samples.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Number of samples	32	22	61	46	65	303	100	24	43	696