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Apple Pomace as a Potential Ingredient for the Development of New Functional Foods

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Apple pomace as a potential ingredient for the development of new functional foods

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Abstract
Apple pomace (AP) is the main by-product of cider industry being mainly composed of carbohydrates and dietary fibre, small amounts of protein, fat and ash. In addition AP is also a good source of phytochemicals such as phenolic acids and flavonoids making AP a valuable source of antioxidants. The common applications of this by-product are the direct disposal to soil in a landfill and for pectin recovery usage. These applications are not sufficient to drain the several tonnes produced every year and studies to valorise the AP for other purposes have gained momentum. AP due to its chemical composition, rich in fibre with significant amounts of antioxidants, can be incorporated in human food-chain thus generating new potential functional foods. Extruded snacks and baked scones were incorporated with increasing levels (0-30%) of AP. The incorporation of AP from the chemical and nutritional analysis was successful with 20% addition in extruded snacks and 30% addition in baked scones. At these levels of incorporation fibre content, phenolic content and antioxidant capacity (DPPH radical scavenging activity, FRAP and β-carotene/linoleic acid system) increased when compared to the products with no AP incorporation. Chlorogenic acid and quercetin were the major phenolic compounds of AP incorporated extruded and baked products. Feruloylquinic acid, isorhamnetin/rhamnetin, phloretin, luteolin and rutin were also present in the AP based products. The AP incorporated baked products also showed the presence of catechin/epicatechin and phloridzin. Nevertheless, compounds other than phenolics affected the antioxidant activities of AP incorporated extruded and baked products probably products resulting from Maillard reaction. These data suggest that AP from a chemical and nutritional point of view can be successfully incorporated in extruded and baked products conferring fibre and antioxidant properties to the final products.

Keywords: Apple pomace, extrusion, bakery, total dietary fibre, phenolic compounds, antioxidant capacity, LC-ESI/MS

Introduction
Functional foods reflect recent consumer interest in convenient food and healthy eating. The US Food and Drug Administration (FDA) suggest functional foods as a food or food ingredients that may provide a health benefit beyond their nutritional content. Included in the target compounds considered to be health benefiting for functional foods are dietary fibre, phytochemicals and antioxidants.
Apple pomace (AP) is the main by-product of cider processing and pose a serious environmental problem due to the large amounts (millions of tonnes in EU alone) produced every year. AP is composed mainly of carbohydrates and dietary fibre, small amounts of protein, fat and ash (Sudha *et al.*, 2007, Wang and Thomas, 1989). AP is also a good source of phytochemicals primarily phenolic acids and flavonoids. Some of the phenolic compounds identified in AP have been correlated with antioxidant capacities using various methods (DPPH, hydroxyl and superoxide anion radical scavenging activity, FRAP) and thereby confirming that the AP is a valuable

source of antioxidants (Cetkovic *et al*., 2008, Diñeiro García *et al*., 2009, Lu and Foo, 2000).

The common applications of this by-product are the direct disposal to soil in a landfill and for pectin recovery usage (gelling agent, stabilizer and source of dietary fibre). As these applications are inadequate to drain the several tonnes produced every year, studies to valorise the AP for other purposes have gained momentum. Among those purposes AP was incorporated in foods especially in baked foods where the emphasis of the studies is on the texture, volume, colour and sensory of the final AP incorporated products (Masoodi and Chauhan, 1998, Sudha *et al*., 2007, Wang and Thomas, 1989). Extruded snack products are predominantly made from cereal flour or starches and tend to be low in protein with low biological value. The incorporation of enriched fibre flours with significant values of antioxidants is a way to improve the nutritional value of these snacks (Ainsworth *et al*., 2007, Stojceska *et al*., 2008a, Stojceska *et al*., 2008b). Baked products, where starch is the major component, will improve their nutritional value if incorporated with fibre enriched flours containing antioxidants (Ajila *et al*., 2008, Rupasinghe *et al*., 2008, Sudha *et al*., 2007, Wang and Thomas, 1989).

AP rich in fibre with significant amounts of antioxidants can be incorporated in human food-chain thus generating new potential functional foods. Although there are few reports on the incorporation of AP in baked products (with lack of information regarding antioxidants) the studies on AP incorporation in extruded products have not been reported. In this study, we present the chemical composition and the antioxidant capacity of extruded and baked products upon addition of AP.

Materials and Methods

Apple pomace

Apple pomace (AP) was provided by Bulmers Limited (Clonmel, Ireland). On arrival AP was freeze dried and coarsely ground and passed through 250 μm sieve and stored in polyethylene bags at -20ºC.

Incorporation in extruded products

Extruded products were prepared from blends of rice flour and wheat semolina in a ratio of (2:1) with different proportions (0, 10, 20 and 30%) of AP on a dry weight basis.

Incorporation in baked products

Baked products were formulated as scones with Odlums Cream flour (Odlum Group, Alexandria Road, Dublin, Ireland). Odlums Cream flour was replaced with 10, 20 and 30% of AP for the different incorporated products.

Chemical characterization

Moisture, ash, fat, protein, starch and total dietary fibre were determined according to the AOAC methods. Protein digestibility and starch digestibility were determined according to the methods described by Onyango *et al.* (2004).

Extraction, determination and identification of phenolic compounds

Phenolic compounds from AP were extracted with water at room temperature. Solid phase extraction (SPE) with C18 cartridges was performed to select the organic compounds from the crude extract and to remove the sugars. The phenolic-rich fraction was concentrated, frozen at -70ºC and freeze dried. Total phenolic content (TPC) was determined using the Folin assay (Ganesan *et al*., 2008). Total flavonoid content (TFC) was estimated according to a method previously described (Liu *et al*., 2009). Proanthocyanidins content (PAC) was determined using the vanillin assay (Sun *et al*., 1998). The phenolic compounds were separated and identified by Liquid Chromatography – Electrospray Ionization Mass Spectrometry (LC-ESI/MS).

Antioxidant capacity evaluation

Antioxidant capacity of phenolic compounds extracts was evaluated by the DPPH radical scavenging activity (Yen and Chen, 1995), FRAP-ferric reducing antioxidant power (Diñeiro García *et al*., 2009) and β-carotene linoleic acid system (Lu and Foo, 2000).

Statistical analysis

All analyses were performed in triplicate. Data were reported as mean ± standard deviation (SD). To determine the difference of means *t*-student test was used. Differences were considered to be statistically significant at $p \leq 0.05$.

Results and Discussion

Chemical characterization

The incorporation of 20 and 30% AP in extruded products changes the chemical composition of the products when comparing to the control. These changes did not prejudice the nutritional value of the products but improve them with the increase of fibre content (Table 1). However, for 30% AP incorporation in extruded products the protein digestibility decreased 50%. It is possible that adding AP with high contents of dietary fibre and polyphenols has promoted the formation of complexes resistant to pepsin action due to the interaction between the proteins and that compounds (Onyango *et al*., 2004, Stojceska *et al*., 2008a). The incorporation of 0-30% AP in baked products increase the fibre content and did not affect the chemical composition of the products when compared to the control (Table 1).

Table 1. Proximate composition of AP, incorporated AP extruded and baked products.

	Moisture %	Ash %	Fat %	Protein %	Starch %	TDF %
AP	7.9±0.4	1.1±0.2	2.3±0.1	3.3±0.1	7.8±0.5	42.1±1.4
EXTRUDED PRODUCTS						
0% AP	8.0±0.0	0.4±0.1	0.0±0.0	10.6±0.0	72.1±5.4	7.0±0.3
10% AP	7.8±0.1	0.4±0.0	0.1±0.0	10.0±0.0	70.1±2.2	9.2±0.7
20% AP	6.2±0.1	0.4±0.0	0.2±0.0	9.9±1.2	63.2±1.3	11.7±0.5
30% AP	5.8±0.1	0.5±0.1	0.2±0.0	8.9±0.2	56.3±0.8	12.5±1.0
BAKED PRODUCTS						
0% AP	2.2±0.4	3.4±0.0	12.7±0.0	14.3±1.8	61.4±2.7	7.8±0.0
10% AP	2.2±0.1	3.4±0.0	12.7±0.1	12.4±0.0	49.9±3.0	11.9±0.1
20% AP	2.7±0.1	3.2±0.2	12.6±0.5	12.3±0.2	27.2±2.2	15.2±0.1
30% AP	2.8 ±0.1	3.1±0.1	12.6±0.8	11.4±0.2	34.4±1.8	17.7±0.2

Determination of phenolic compounds

Incorporation of AP in extruded and baked products increased the content of TPC, TFC and PAC (Figure 1). Similar increase in TPC was also observed upon incorporation of other by-products such as cauliflower by-products (Stojceska *et al*., 2008a), and mango peel powder (Ajila *et al*., 2010) in extruded snacks and upon the incorporation of different levels of apple skin powder in muffins (Rupasinghe *et al*., 2008) and mango peel powder in soft dough biscuits (Ajila *et al*., 2008). The recoveries of TPC, TFC and PAC calculated from the expected and observed values showed a decreasing trend with the increasing AP incorporation. It is likely that polymerization was promoted by extrusion and bakery which affected the extractability of such compounds. And the more phenolic compounds were incorporated the higher was the polymerization.

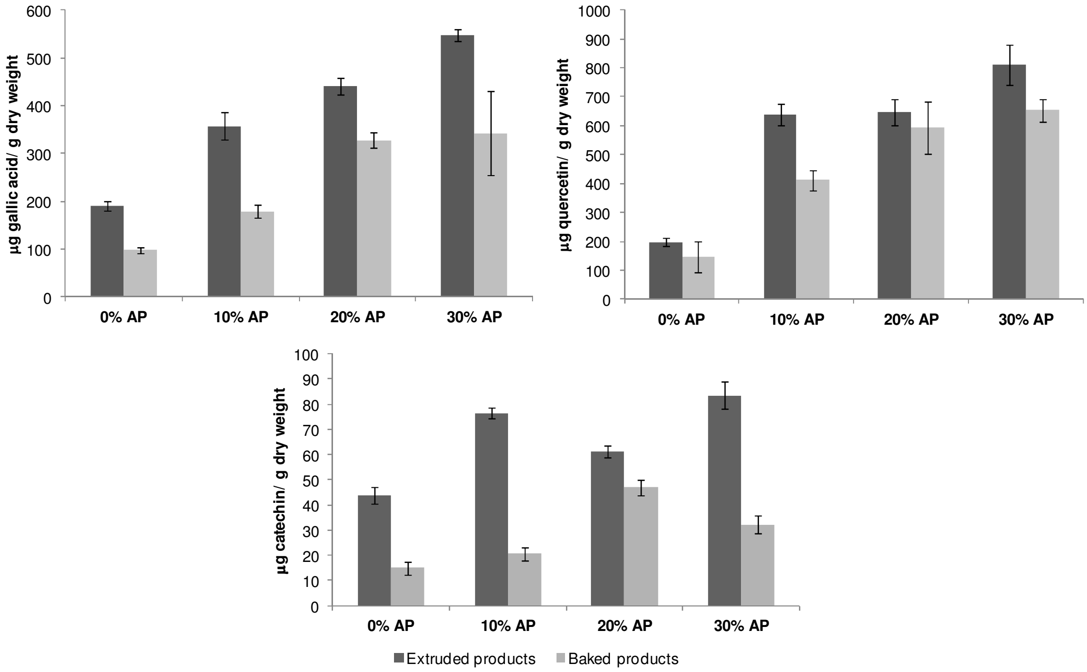

Figure 1: Results of TPC, TFC and PAC in AP incorporated extruded and baked products.

Antioxidant capacity evaluation

The incorporation of AP in extruded products significantly increased the antioxidant activity measured by DPPH radical scavenging activity, FRAP and *β*-carotene/linoleic acid system when compared to the control (Figure 2).

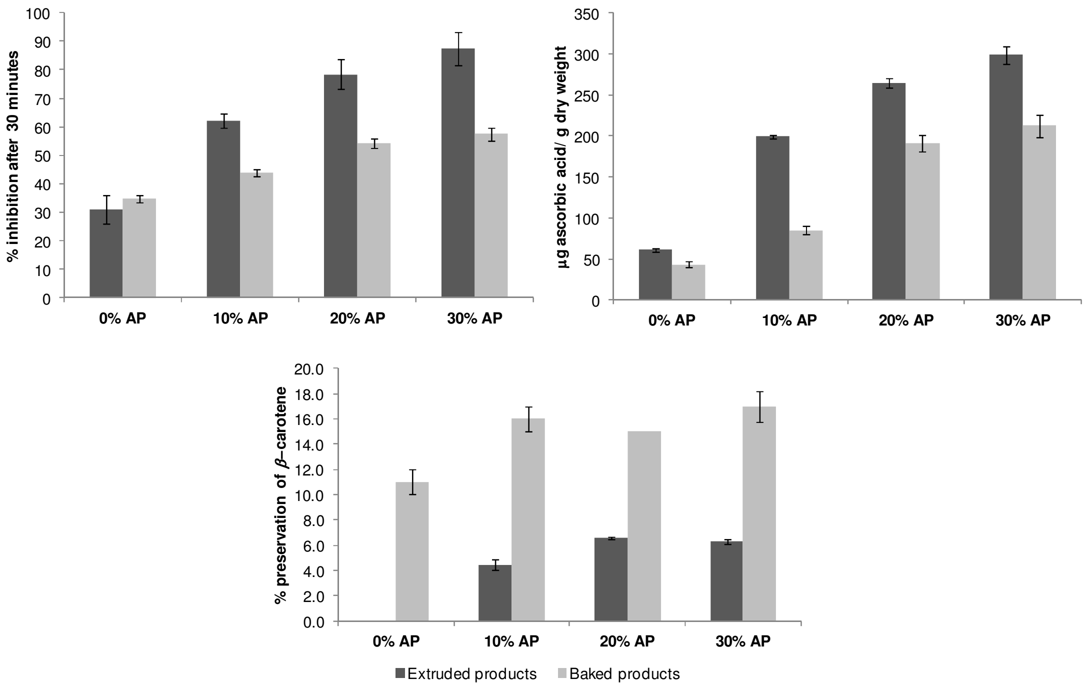

Figure 2: Results of DPPH radical scavenging activity, FRAP and *β*-carotene/linoleic acid system in AP incorporated extruded and baked products.

Identification of phenolic compounds by LC-ESI/MS

The major phenolic compounds of AP incorporated extruded and baked products were chlorogenic acid and quercetin (Figure 3). Other chromatographic peaks corresponding to feruloylquinic acid, isorhamnetin/rhamnetin, phloretin, luteolin and rutin were present in AP incorporated extruded and baked products. The AP incorporated baked products also showed the presence of catechin/epicatechin and phloridzin. The low value observed in extruded products for *β*-carotene/linoleic acid system can be attributed to the absence of flavanols and most of the quercetin glycosides present in AP. That value was slightly higher in baked products maybe due to the presence of catechin/epicatechin. A study by Lu *et al.* (2000) had shown that there is direct correlation between the lower molecular weight procyanidins and quercetin glycosides and the excellent activity measured by the *β*-carotene/linoleic acid assay. The AP incorporated baked products showed higher presence of all the phenolic compounds identified than the AP incorporated extruded products. Phloridzin and catechin/epicatechin were two compounds absent in extruded products. However, it was seen that extruded products had higher antioxidant activities (DPPH, FRAP) than baked products. This result strongly suggests that compounds other than phenolics were affecting the antioxidant capacity. A well known factor is the Maillard reaction products that are formed during heat processing such as extrusion and bakery that could influence the antioxidant capacity (Pokorny, 2003).

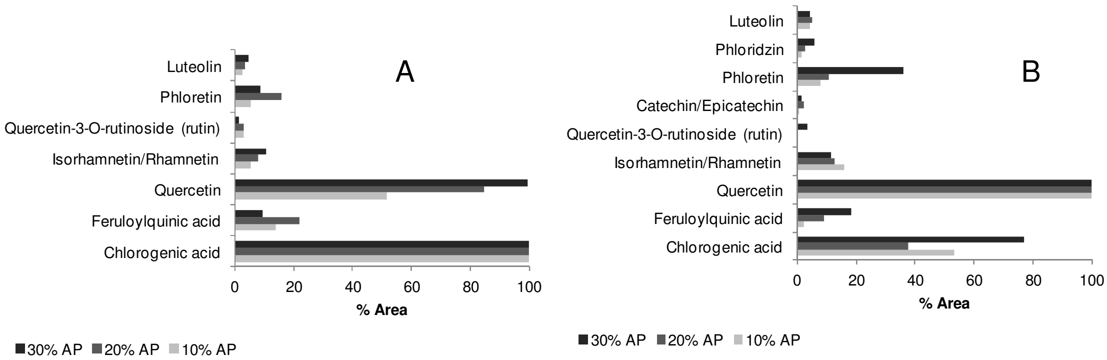

Figure 3: Percentage areas of phenolic compounds identified in AP incorporated extruded (A) and (B) baked products.

Conclusions

AP from a chemical and nutritional point of view can be successfully incorporated in extruded and baked products conferring fibre and antioxidant properties to the final products.

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