A diet rich in dietary fibre from cocoa improves lipid profile

LAURA BRAVO1*, ELENA LECUMBERRI1, RAQUEL MATEOS1, SONIA RAMOS1, MARIA IZQUIERDO-PULIDO2, LUIS GOYA3

1. Department of Metabolism and Nutrition, Instituto del Frio - Instituto de Ciencia y Tecnología de Alimentos y Nutricion - ICTAN Spanish Council for Scientific Research (CSIC), C/ Jose Antonio Novais 10, 28040 Madrid, Spain
2. Department of Nutrition and Food Science, Facultat de Farmacia, Universidad de Barcelona, Av. Joan XXIII, s/n 08028 Barcelona, Spain

*Corresponding author

ABSTRACT: By-products obtained from the industrial processing of cocoa beans constitute an important source of dietary fibre (DF) containing appreciable amounts of polyphenolic compounds. Such a fibre-rich cocoa product (FRCP) could have potential applications as a functional ingredient due to its DF content (mainly insoluble DF) and antioxidant activity. We studied the effect of the FRCP in an animal model of hypercholesterolaemia and observed a cholesterol- and triglyceride-lowering effect derived from the consumption of this product for 3 weeks. A reduction of biomarkers of oxidative stress was also detected. These beneficial properties, together with the effect increasing faecal bulking, suggest that this cocoa product could be of interest as a functional food ingredient or nutraceutical.

INTRODUCTION

Many epidemiological and intervention studies have established a relationship between the consumption of dietary fibre (DF) and a protection against common diseases, both associated to the gastrointestinal tract (constipation, diverticulosis, inflammatory bowel diseases or colorectal cancer) and metabolic diseases like obesity, cardiovascular disease (CVD) and type-2 diabetes mellitus (1-8). Recommendations establish a minimum daily intake of dietary fibre of 25 g in order to prevent pathologic conditions derived from a low DF intake, and even 30-35 g/d are advised to prevent CVD (2, 8). However, in Western countries with a high consumption of refined cereals and animal products, daily consumption of DF is well below the recommended amounts, which has been clearly linked to the increased prevalence of some of these pathologies. To compensate for this, in the last decades the agro-food industries have set up for the identification, obtention and characterization of different sources of DF suitable for addition into foods and foodstuffs, or to be used as dietary supplements. By-products from the food industry have proven to be an excellent source of such DF-rich materials. DF is especially abundant in cocoa shells (9), which are a major by-product obtained from the important cocoa industry. Tones of shells are produced worldwide every year and disposed of as waste, which represents a major environmental problem. However, cocoa shells can be used as a new source of DF, which would solve this problem and add value to this by-product. On the other hand, cocoa and cocoa products are recognized to have potential implications preventing or ameliorating atherosclerosis and cardiovascular disease risk factors. Improvement of lipid profile and endothelial function, decrease of biomarkers of lipid peroxidation or inhibition of platelet activation and inflammatory-cytokines production are some of the mechanisms of action of cocoa decreasing risk markers of CVD as seen in animal and human intervention studies (10-16). Most of these health-promoting effects are attributed to the antioxidant and anti-inflammatory action of the polyphenolic fraction of cocoa, which is comprised mainly of flavanols like the monomeric catechin and epicatechin, or oligomeric procyanidins (from dimers to decamers) (17). Since cocoa shells contain appreciable amounts of polyphenolic compounds, some of these beneficial effects could also be retained in this by-product. The aim of the work reported here was to characterize a new fibre-rich cocoa product (FRCP) obtained by a Spanish cocoa industry, assessing some physiological effects derived from the consumption of this product by hypercholesterolaemic rats.

RESULTS AND DISCUSSION

Composition of the Fibre-Rich Cocoa Product

The fibre-rich product obtained from cocoa shells was very rich in dietary fibre, containing over 60 % (dry matter basis) of total dietary fibre (TDF), as shown in Figure 1. The DF was made of mainly insoluble fraction (insoluble dietary fibre, IDF), which amounted to 50.4% of the dry matter (d.m.) and contained neutral sugars (14.5% d.m.), uronic acids (3.5% d.m.) and Klason lignin (32.5% d.m.). The soluble dietary fibre (SDF) fraction was also appreciable, up to 10.1% d.m. This fraction was composed of mainly uronic acids (7% d.m.) and neutral sugars (3% d.m.). A detailed analysis of the carbohydrate composition of the FRCP was reported elsewhere (9). It was shown that cellulose, hemicellulose and some pectic substances where the main polysaccharides in the IDF fraction, while SDF was mainly made of mainly uronic acids (7% d.m.) and condensed tannins (4.5% d.m.) (Figure 2). Although the amount of soluble polyphenols...
was relatively low in comparison with other cocoa products, the presence of these compounds provided the FRCP with antioxidant properties, as shown by the FRAP (72 mmol TE/g d.m.) and ABTS (8 mmol TE/g d.m.) tests. Again, the antioxidant activity was lower than that found in other polyphenol-rich foods and beverages like wine, tea, fruit juices, chocolate drinks, etc. but it can be considered relevant for a fibre-rich material such as the cocoa-derived product under study. Therefore, both the dietary fibre content and the slight yet appreciable antioxidant capacity of the fibre-rich product obtained from cocoa shells suggested that it could have interesting physiological effects in vivo. To test this, we designed an animal experiment where hypercholesterolaemic rats consumed the FRCP during 3 weeks and determined the effect of the FRCP on faecal weight, lipid profile and biomarkers of antioxidative damage to lipids and proteins.

Faecal bulking effects of the Fibre-Rich Cocoa Product
One of the best known properties of DF is its faecal bulking capacity. Non-digestible carbohydrates in the DF pass through the stomach and small intestine resisting hydrolysis by the digestive enzymes, retaining water and other dietary and secreted intestinal contents. When arriving to the large intestine, colonic microbiota can degrade the soluble, fermentable DF fraction, producing short chain fatty acids and gas, whilst cellulose and other components of the IDF fraction resist colonic fermentation and are excreted in faeces. All this results in an increased faecal bulk and water retention in the faeces, and is the basis for the well-known effect of DF preventing constipation and regulating intestinal transit time. As it is shown in Figure 3, consumption of a high-cholesterol diet increased the total faecal output as compared with rats consuming the control diet (both diets contained 10% cellulose). Supplementation of the high-cholesterol diet with the cocoa product as the only source of DF caused a further increase in the total faecal excretion, both of dry matter as well as of water in the faeces, thus proving a remarkable bulking effect of the FRCP.

Effects of the Fibre-Rich Cocoa Product on serum lipids
The lipid profile of the two control groups (fed the standard and high-cholesterol diets containing cellulose) and the experimental group fed the high-cholesterol diet supplemented with the FRCP is shown in Table 1. As can be seen, consumption during three weeks of the high-cholesterol diet caused a significant increase in the serum total and LDL-cholesterol and triglyceride levels, concomitant with a decrease of HDL-cholesterol levels. This resulted in an increase of the atherogenic index of this diet (Figure 4). When the high-cholesterol diet was supplemented with the FRCP, both total and LDL-cholesterol serum concentration were decreased, although basal levels found in the control animals were not achieved (Table 1). The FRCP had no effect on HDL-cholesterol. However, triglyceride concentrations were reduced to values comparable to the controls. Therefore, supplementation of a fatty diet as the one fed to the experimental animals in this study showed a slight yet statistically significant hypocholesterolaemic effect and a marked hypotriglyceridemic action. In parallel, a notorious reduction of the atherogenic index was achieved (Figure 4). Considering that hyperlipemia is one of the main risk factors for CVD, the observed effect of the FRCP is of great relevance, showing that this source of DF (mostly insoluble fibre) could have a protective effect on cardiovascular health. This effect could be ascribed to the fibre content, since DF (mostly soluble, fermentable fibres) have been shown to reduce cholesterol levels directly through an inhibition of fat digestion and absorption, or indirectly through the effect of propionate formed during colonic fermentation of SDF inhibiting cholesterol and fatty acid synthesis (3, 25, 26). However, polyphenols in the FRCP can also be partly responsible for the observed hypolipidemic effects.

<table>
<thead>
<tr>
<th></th>
<th>Control (mg/dL)</th>
<th>High-cho. (mg/dL)</th>
<th>FRCP (mg/dL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
<td>201.0</td>
<td>250.0</td>
<td>210.0</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>125.0</td>
<td>252.0</td>
<td>150.0</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>60.0</td>
<td>70.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>120.0</td>
<td>150.0</td>
<td>90.0</td>
</tr>
</tbody>
</table>

Table 1. Serum lipids (mg/dL) in the rats fed the three experimental diets.
As mentioned, cocoa polyphenols have been shown to improve lipid profile and increase resistance of LDL against oxidation, among other beneficial effects of cocoa polyphenols against atherosclerosis and cardiovascular disease (10-16, 23).

**Effects of the Fibre-Rich Cocoa Product on biomarkers of lipid and protein peroxidation**

Malondialdehyde (MDA) and carbonyl concentrations were determined in serum samples as biomarkers of oxidative damage to lipids and proteins, respectively. Both biomarkers were significantly increased in high-cholesterol control animals as compared to the control rats consuming the normal diet without cholesterol (Figure 5). This clearly indicated that hypercholesterolaemia was associated to an increased lipid and protein peroxidation. However, although protein carbonyls were not affected, MDA levels were significantly reduced in the high-cholesterol group consuming the cocoa product as compared with the high-cholesterol controls (127%), reaching values even lower (91%) than those in the control animals (100%). This clearly suggests a protection by the antioxidant polyphenols in the FRCP against lipid peroxidation.

**EXPERIMENTAL SECTION**

Dietary fibre in the FRCP was analysed by the AOAC method modified in our laboratory (17), determining neutral sugars, uronic acids and Klason lignin. Soluble polyphenols were extracted from the FRCP and total polyphenols and condensed tannins determined as described elsewhere (19). Antioxidant capacity was evaluated in the extracts by the FRAP assay as an evaluation of the reducing power of the sample (20), and the TEAC method (21) to assess its free radical scavenging capacity. Results are expressed as mmol of Trolox per gram of dry matter.

**CONCLUSION**

In summary, cocoa shells, which are the major by-product of the industrial processing of cocoa beans, can be considered as a rich source of dietary fibre. A product obtained from this by-product showed to be very rich in DF, mostly insoluble, but also containing up to 10% of soluble fibre. This product retains some polyphenolic compounds that confer it with appreciable antioxidant activity. Consumption of the FRCP may have health beneficial effects, since it has a remarkable hypotriglyceridemic effect and a slight hypocholesterolaemic action in an animal model of dietary-induced hypercholesterolaemia, preventing oxidative damage to lipids. All these results suggest that cocoa by-products could be used as a functional food ingredient.

**ACKNOWLEDGEMENTS**

The authors acknowledge the support of Nutrexpa S.L. (Spain).

**REFERENCES**