Comparative Study on Apparent Digestibility, Absorption and Distribution of Fatty Acids in Rats Fed Diets Containing either Beef Tallow or Plant Oils.

A. Fotovati, T. Hayashi, K. Jono and T. Ito

Laboratory of Biological and Functional Chemistry, Dept. of Biological Resources and Environmental Science, Graduate School of Kyushu University (Former affiliation was the Lab. of Chem. and Tech. of Anim. Products, Fac. of Agricu. Kyushu Univ.) 6-10-1 Hakozaki, Higashi-ward, Fukuoka 812-8581, Japan

ABSTRACT: The digestibility and absorption of dietary lipids depend on several factors including their fatty acid composition. In this study, apparent digestibility (AP) and the fatty acid profile of different dietary lipids, rich in saturated (SFA) and mono- or poly-unsaturated fatty acids (MUFA, PUFA), and also effects of some fatty acids especially stearic acid (18:0), was studied in rats. Twenty-four SD-male rats (7 weeks old) were raised for 6 weeks on 4 different diets containing 12% of beef tallow canola oil, olive oil or safflower oil. Patterns of distribution of different fatty acids in body tissues of rats was described. Rats raised with beef tallow, with high content of 18:0, showed significantly lower apparent digestibility compared to other diets with lower 18:0 content (P<0.05). Stearic acid was one of the main fatty acid of fecal undigested fats. It can be concluded that poor digestibility of beef tallow is due to higher content of 18:0. Not significant cholesterolemic effect of beef tallow in spite of its high contents of palmitic acid was also attributed to its high content of stearic acid, which is considered to be an exceptional non-cholesterolemic and even cholesterol-lowering SFA.

Key Words: Rats, diets, Fatty Acids, Beef tallow, Vegetable Oils, Digestibility

INTRODUCTION

The digestibility of a food depends on the physio-chemical properties of its contents and the physiological status of the animal. Lipids are one of the major constituents of animal and human food. Dietary lipids used by animals and humans have two main origins, animals and plants. One of the important topics of lipid metabolism is the “fate of ingested lipid” in the body. Although it is clear that the ingested lipids undergo several digestive and absorptive processes which break down and change them to the chylomicrons, digestibility of different dietary lipids and patterns of their distribution is still under the investigation (Fotovati and Ito, 1998). The difference of origin results in a very important difference in fatty acid composition. As a general rule, the level of saturated fatty acids (SFA) in fats with animal origin is more than those with plant origin and in the case of unsaturated fatty acid, including mono (MUFA)- and poly (PUFA)-unsaturated fatty acids the situation is reversed. However, there are some exceptions, such as palm oil which is of plant origin but contains high levels of SFAs or fish oil which contains high levels of UFAs. Studies have shown that these groups of FAs have different digestibility. Studies on fat digestibility have shown that it differs according to the type of ingested fats. For example, fat digestibility in the rats fed beef tallow (high SFA) was significantly lower than that of rats fed fish oil (high PUFA) or peanut oil (De Schrijver et al., 1991). It is believed that such differences are due to difference in FA content. For example some SFAs, such as stearic acid (18:0) showed poor digestibility. Poor digestibility of such fatty acids also affects dietary lipids as a whole. Previous studies have also shown some patterns of distribution and metabolism of different dietary ingested fats rich in SFA, PUFA and MUFA in the rat’s body (Tajima et al 1995, Kawahara et al 1997).

In this study, patterns of digestion, absorption and distribution of different fatty acid containing of different dietary lipids including beef tallow as a lipid with animal origin and canola oil, olive oil and safflower oil with plant origin have been comparatively investigated.

MATERIALS AND METHODS

Animal Experiment:

Twenty four 7-week old male SD-rats were raised for 7 weeks, the first week on a commercial diet for adaptation and then, they were divided into 4 groups and fed different diets containing 12% of either beef tallow, canola oil, olive oil or safflower oil as fat source. Weight gain and feed intake were measured every other day. Fecal out-put was also measured weekly throughout the study. After six weeks, the rats, after anesthetisation by ether, were killed (according to the guidelines for Animal Experiment in Kyushu University) and their abdominal fat mass and liver were dissected.
**Lipid Extraction and analysis:**

Fat content of diet and feces and also abdominal fat, liver and muscle was extracted by Folch’s method (Folch et al. 1957). Apparent lipid digestibility (%) was calculated as dietary lipid intake minus fecal lipid excretion divided by dietary fat intake and multiplied by 100. Fatty acid composition of extracted lipid was analysed by gas chromatography (GC) as previously described (Kawahara et al., 1997).

![Fig.1. Fatty acid composition of experimental diets](image1)

**TOTAL CHOLESTEROL MEASUREMENT**

Total cholesterol of serum was measured by enzymatic method using T-Chol C Kit (Wako, Japan). The amount of total cholesterol calculated as mg/dl.

**STATISTICAL ANALYSIS**

Results are shown as means ± SEM. The statistical significance of difference between groups was assessed by Student’s unpaired t test.

**RESULTS**

There was no significant difference in final weight, daily weight gain, daily feed intake or fecal output among the dietary groups. The proportion of stearic acid (18:0) in the feces was higher than that in the diet for all dietary groups. Apparent digestibility of beef tallow was significantly lower than that of all other dietary lipids (P<0.05). Olive oil diet showed the lowest and safflower oil diet the highest feed efficiency rate. Fatty acid composition of diet is shown in Figure 1. Oleic acid was major fatty acid in all experimental diets. The composition of fatty acids detected in the feces is shown in Figure 2. Palmitic acid (16:0), stearic acid (18:0) and oleic acid (18:1) were the three major fatty acids could be detected in the feces of rats of all dietary groups. In the canola group, there were some other fatty acids detected but all are grouped together because they were present in small amounts. The patterns of fatty acid distribution in the different tissues of the rats is shown in Figure 3. In all the dietary groups and in all tissues the amount of Oleic acid (18:1) was the highest compared to the other 8 fatty acids determined. Fatty acid composition of abdominal fat and muscle showed a close relationship to that of diet in all dietary groups. Although serum total cholesterol in the beef tallow–fed group was higher, the difference was not significant (P>0.05).

**DISCUSSION**

The results reported in here show different patterns of digestion, absorption, distribution and metabolism of fatty acids contents of dietary lipids of two major groups, animal fat (beef tallow) and plant oils (canola, olive and safflower oil) and also how their metabolism can affect the diet metabolism itself in rat body. The results suggested that the different dietary fatty acid after ingestion showed various patterns of digestion and absorption. Beef tallow, as an animal fat rich in SFA, particularly 18:0, showed poor digestibility, compared to dietary lipids with plant oil.
In our study, the main fatty acids detectable in the feces were palmitic acid (16:0) stearic acid (18:0) and oleic acid (18:1) and the proportions of the first two acids were higher than the latter. It has been shown that in spite of low level of 18:0 in vegetable oil, e.g. canola (4.42%), olive (2.63) and safflower oil (2.23%), its proportion in the feces is considerably higher (22.55%, 26.46% and 35.18% respectively), indicating lower digestibility of this fatty acid. In beef tallow, although the fecal stearic acid proportion (24.1%) was not apparently as high as canola and safflower, lower apparent digestibility of beef tallow (92.3%) was mostly due to the high content of 18:0 in it (10.04%). Palmitic acid and oleic acid were two other major FAs in the feces. It indicates that other fatty acids, especially PUFAs that formed major parts of these dietary lipids were completely absorbed. These results suggest poor digestibility of SFA especially 18:0 and are supported by results of several studies.

For example, several studies have shown that cocoa butter showed poor availability in rats (Appgar et al. 1987, Chen et al. 1989, Monsma et al. 1996) and also to a lesser extent in humans (Mitchell et al. 1989). Some studies have shown that stearic acid (18:0) of naturally occurring dietary triacylglycerols have a poor absorption in the gastrointestinal tract of rats (Monsma et al, 1995). By using orally administrated stable-isotope-labeled fatty acid substrates in human, it has been found that absorption efficiency for $^{13}$C stearic acid is 78% compared with 98-99% for oleic and linoleic acids (Jones et al 1985). The reason of lower absorption of these kind of fatty acids is poorly described. There are some studies indicating that even stereospecific distribution of fatty acids on triglycerol structures can affect digestibility of fat in the diet (Redgrave et al 1988, Bracco 1994).

On the other hand, part of fecal oleic and palmitic acid is actually originated from unabsorbed stearic acid. Studies in laboratory animals (Elvoson 1965 and Bonanome et al 1992) and in human (Bonanome et al, 1988) suggest that much of stearic acid is rapidly converted into oleic acid through the desaturation at omega-9 position. It has also been shown that shortening of stearic acid in gastrointenstinal tract results in palmitic acid production (Jones et al 1999).

Although as a general concept, cholesterolemic effect of SFA and cholesterol-lowering effect of PUFAs has been shown (Mattson and Grundy 1985, Grundy et al 1990), feeding beef tallow with high content of palmitic acid, a strong cholesterolemic fatty acid (Salter et al, 1998, Snook et all 1999), didn't show a significant cholesterolemic effect, compared to oil with plant origin. Lack of significant cholesterolemic effect of beef tallow could also be attributed to its high
content of stearic acid. There are some studies suggesting lack of cholesterolemic and even cholesterol-lowering effect of stearic acid (Nestel et al 1998). Some studies suggested that such effect of 18:0 could be attributed to its poor absorption in the intestine and also lower transportation of fatty acid after absorption (Bergstedt et al, 1990 and Kritchevsky 1994).

CONCLUSION

The results of this study showed that fatty acid composition of diet is a major factor determining the "fate of intaked lipid" in the body when high-fat diets were fed to the rats. Digestibility, absorption and pattern of distribution of intaked fatty acid can be affected by themselves. Stearic acid (18:0) contents was shown as a major cause of decreased digestibility in various dietary fats, especially in beef tallow diet. Additionally, it was shown that the effect of diet on fat metabolic system such as cholesterol synthesis could also be affected by their fatty acid contents. Not significant cholesterolemic effect of beef tallow can be attributed to high contents of stearic acid, an exceptional cholesterol-lowering SFA.

ACKNOWLEDGEMENT

This study was partly supported by a grant from Japan Ministry of Education and Welfare and Uehara Memorial Foundation

REFERENCE


Email: fotovati@agr.kyushu-u.ac.jp
fotovati@hotmail.com