Absorbability and weight gain by mice fed methyl glucoside fatty acid polyesters: potential fat substitutes

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Male mice (n = 27) were fed a control diet consisting of a fat free diet plus 11% peanut oil or two methyl glucoside polyester (MGP), experimental diets for 10 days. The experimental diets consisted of fat-free diet plus 11% of MGP, 100% oleate, or 90:10 stearate:oleate. Absorbability, percent recovery of the oils and fats, and percent mean body weight gain were determined. The mice consuming 100% oleate MGP and the mice consuming 90:10 stearate:oleate MGP lost more weight (−10.1%) and (−7.4%), respectively, than the mice consuming the control diet, P < 0.05. Subsequent fat analysis showed that the 100% oleate MGP were almost completely recovered from the feces, indicating close to zero absorbability, while the MGP (90:10 stearate:oleate) were partially absorbed at 66.8%. No anal leakage or death was observed. Methyl glucose fatty acid polyester may serve as a potential alternative fat substitute.

Keywords: mice; methyl glucoside polyester; absorption; fat substitute

Introduction

The diet of most Americans contains 35%–40% of total dietary calories as fat. High consumption of fat is often linked to certain diseases, such as heart disease, cancer, and obesity.[1] Recommendations to the American public suggest reduction of fat consumption to 28%–35% of total calories is prudent.[2-4]

Recent studies have been aimed at developing carbohydrate-based fatty acid polyesters and alkyl glycoside fatty acid polyesters as fat substitutes to replace edible fats and oils in the diet.[5-10] One proposed method to reduce caloric value of edible fats and oils in foods is to prepare fatty acid esters of carbohydrates and sugar alcohols with similar functional and physical properties but reduced digestion and absorption.

Alkyl glycoside fatty acid polyesters have functional and physical properties resembling conventional triglycerides.[7] Preliminary feeding trials with mice suggest that methyl glucoside polyester is partially absorbed and can help reduce weight.[6] Carbohydrate polysters such as sucrose polyester (Olestra), and alkyl glycoside polyester are not fully hydrolyzed by intestinal lipases due to steric hindrance and consequently are poorly absorbed.[6,11]

The fat-like nature of methyl glucoside fatty acid polyester and the potential for use in weight-reduction therapy led us to study the differences in absorbability and weight gain in mice consuming methyl glucoside polyester of different fatty acid composition.

Materials and methods

Synthesis of methyl glucoside polyester

The synthesis of pure methyl glucoside fatty acid polyesters was based on procedures we described previously.[7]

Animals and diet

Male (n = 27) adult mice with mean ± SEM body weight of 29.4 ± 0.5 were used. The 27 Swiss Webster mice were raised at the Lab Animal Resource Center, Washington State University, Pullman, WA, USA.

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After 7 days' adjustment period, the mice were randomly assigned by body weight into groups of three and housed in shoe-box cages in a temperature- and light-controlled room. The mice were divided into three groups and fed the control diet, and the two experimental diets. Two types of methyl glucoside polyester (MGP) experimental diets with different fatty acid compositions were fed to the mice, namely: (1) fat-free diet plus 11% (wt/wt) MGP containing 100% oleate and (2) fat free diet plus 11% MGP (90:10 wt/wt stearate:oleate). The fat free control diet contained 11% wt/wt peanut oil. Each group (n = 9) of mice was fed an average of 3 g diet/day/mouse every other day. In other words, known amounts of diets were provided to each group/day. Water was allowed ad libitum. The mice were observed daily for signs of abnormality, anal leakage, mortality, depression, and consumption pattern.

Analysis

Stools were collected every other day/group and weighed. Mice were weighed at day 0 and day 10. Food consumption for each group of mice was recorded every other day. This was obtained by subtracting the unconsumed diet from the initial diet supplied. Fat in the feces and percent absorption were determined according to the method of Van de Kamer.[12] Percent recovery of test fats and oils was calculated after extraction as we previously described[6] by dividing the amount recovered in the feces by the amount eaten. Qualitative evaluation of the extracted fats and oils was performed by thin layer chromatography (TLC) as previously described.[5,6]

Statistical methods

Data were subjected to analysis of variance and Duncan's multiple range test using the SAS program (SAS Institute, Cary, NC, USA)[13] to determine differences in mean body weight gain ($P < 0.05$).

Results and discussion

Table 1 shows the composition of the control diet. Low dose (11%) supplementation of dietary fats with methyl glucoside polyester (MGP), a potential fat substitute, showed that the lowest mean body weight gain occurred in mice fed MGP consisting of 100% oleate (*Table 2*). There were significant differences in mean body weight gain in mice fed the control and the two experimental diets, $P < 0.05$. The mean body weight gain in the control group was 12.5%. *Table 2* shows a 10.1% and 7.4% loss in body weight of male mice fed MGP (100% oleate) and MGP (90:10 stearate:oleate), respectively, after 10 days. These results agree with our previous data[6] in which liquid raffinose polyester and MGP (50:50 oleate:stearate) were fed to mice. However, the design of the present study differed from that of the previous study[6] in that MGP of different fatty acid compositions were fed to the mice. No absolute correlation was observed between weight gain and differences in fatty acid composition of the experimental diets. Mean body weight gain in mice may depend on the fatty acid moiety on the MGP and the ability of the individual intestinal lipases to digest the polyesters. We do not know at this time whether the degree of saturation had any effect on apparent digestibility. Mattson and Nolen[11] reported that polyol polyesters with 4–8 ester groups are not hydrolyzed and digested by pancreatic lipase, and consequently are not absorbed across the intestinal mucosa. The possibilty of using alkyl glucoside polyesters in weight reduction was suggested in our previous report.[6] These polyesters[6,7] are large molecules inaccessible to the lipases due to steric hindrance. In addition, the glycosidic linkage makes alkyl glucoside polyester a poor substrate for lipase catalysis.

Table 3 shows the mean food consumption, the mean stool weight, percent absorption and recovery of the control, and experimental fats and oils. About 7%–8% of all the peanut oil triglyceride in the control diet was recovered while 92% was absorbed. Mattson and Nolen[11] reported 96% absorption of triolein in rats. In contrast, almost all the MGP (100% oleate) was recovered from the feces, indicating near zero digestibility and absorbability. Analysis of fat in the feces and percent absorption by the method of Van de Kamer[12] and TLC[5,6,7] indicated no hydrolysis of the 100% oleate MGP. Future work will focus on the use of radiolabeled MGP to demonstrate zero absorbability of the 100% oleate MGP. The MGP (90:10 stearate:oleate) was recovered in 33.2% yield indicating about 66.8% absorption. The reasons for the differences in absorbability of liquid versus solid MGP are

Table 1 Composition of the diet

Ingredient	Dry wt (%)
Casein (vitamin-free)[a]	17.1
DL-Methionine	0.2
Sucrose[a]	62.9
Cellulose[a]	4.4
Vitamin mixture[a,b]	0.9
Mineral mixture[a,c]	3.4
Calcium carbonate[a]	0.4
Lipid supplement[d]	10.7

[a] Teklad, A Harlan Sprague Dawley Inc. Company, Madison, WI.
[b] Vitamin mixture (as g/kg), designed to be used at 1% of diet: p-aminobenzoic acid, 11.0; ascorbic acid, coated (97.5%), 101.7; biotion, 0.04; vitamin B_{12} (0.1% trituratin in mannitol), 3.0; calcium pantothenate, 6.6; choline dihydrogen citrate, 349.7; folic acid, 0.2; inositol, 11.0; menadione, 4.9; niacin, 9.9; pyridoxine HCL, 2.2; riboflavin, 2.2; thiamin HCL, 2.2; dry vitamin A palmitate (500,000 U/g), 4.0; dry vitamin D_3 (500,000 U/g), 0.4; dry vitamin E acetate (500 U/g), 24.2; corn starch, 466.7.
[c] Mineral mixture (as g/kg), designed to be used at 3.5% of diet: calcium phosphate (dibasic), 500.0; sodium chloride, 74.0; potassium citrate (monohydrate), 220.0; potassium sulfate, 52.0; magnesium oxide, 24.0 manganous carbonate, 3.5; ferric citrate (USP), 6.0; zinc carbonate, 1.6; cupric carbonate, 0.3; potassium iodate, 0.01; sodium selenite, 0.01; chromium potassium sulfate, 0.6; sucrose (fine powder), 118.0
[d] Peanut oil added to the fat deficient diet or methyl glucoside fatty acid polyester added in place of peanut oil.

Table 2 Weight gain in mice fed methyl glucoside fatty acid polyesters

Diet	Sex (n = 9)	Mean body wt ± SEM (g) Day 0	Day 10	% Mean body wt gain
Control[a]	M	29.5 ± 0.7	33.2 ± 0.7	12.5 (A)
MGP[b]				
100% OL	M	30.5 ± 0.2	27.4 ± 0.9	-10.1 (B)
90:10 ST:OL	M	28.2 ± 0.3	26.1 ± 0.4	- 7.4 (B)

[a] Control diet = fat free diet + 11% peanut oil.
[b] MGP = methyl glucoside polyester, 11%; OL = oleate, ST = stearate.
Means with the same letter are not significantly different at $P < 0.05$, n = 9.

Table 3 Food consumption, percent absorption and recovery of fats and oils

Diet	Sex (n = 9)	Mean food consumption wt/d/mouse (g)	Mean stool wt/d (g)	% Absorption	% Recovery	Anal Leakage	Death	Depression
Control	M	2.8 ± 1.4	5.1 ± 1.9	92.4	7.6	0	0	None
MGP[a]								
100% OL	M	3.2 ± 1.6	6.8 ± 0.9	0.0	102.1	0	0	None
90:10 ST:OL[b]	M	2.9 ± 1.0	7.8 ± 1.3	66.8	33.2	0	0	None

[a] MGP = methyl glucoside polyester, 11%.
[b] OL = oleate, ST = stearate.

not entirely clear and warrant further investigation. It is possible that the various fatty acids are digested to different extents by the lipolytic enzymes of the intestinal tract. Comai et al.[14] reported that hydrogenated soybean oil is poorly absorbed by obese Zucker rats. Hydrogenation of unsaturated fatty acids increases the melting point of the fat, making it difficult to digest and absorb.[14] Since the MGP (90:10 stearate:oleate) is essentially solid, it follows that digestion and absorption will likewise be reduced. As reported earlier,[6] male mice seemed to consume more food and excrete more feces than the females (data not shown). In the present report, the mice on experimental diets consumed more food and excreted more feces than mice on control diet (*Table 3*). The reduction in absorption was accompanied by an increase in food consumption.

Previous in vitro lipase hydrolysis and in vivo studies[6,7] confirm the reduced digestibility and absorbability of MGP. Steric hindrance and degree of saturation may be responsible for the poor digestibility of MGP by lipases. In addition, the glycosidic bond in MGP may not be a good substrate for intestinal lipases.

At 11% supplementation of MGP for dietary fat, no signs of abnormal behavior, anal leakage, mortality, or depression were observed throughout the study period (*Table 3*). However, because of infrequent fights among the male mice, it is advisable to separate them into individual cages instead of housing three mice per cage.

The present findings suggest that low-dose substitution of MGP as a potential fat substitute in the diet is potentially safe and may be useful in weight reduction therapy. There is a differential absorption of liquid and solid MGP in vivo. What is not known is whether MGP, because of its lipophilic nature, will influence the absorption of fat soluble vitamins and other nutrients. It is also possible that deficiency in essential fatty acids in the experimental diets may have contributed in some degree to the observed weight loss. Future long-term feeding trials will attempt to address this as well as the effects of MGP on fat soluble vitamins, cholesterol, bile salt pool and its hepatic synthesis, and fecal losses.

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References

1 Bracco, E.F., Baba, N., and Hashim, S.A. (1987). Polysiloxane: potential noncaloric fat substitute; effects on body composition of obese Zucker rats. *Am. J. Clin. Nutr.* **46,** 784–789
2 National Research Council. (1982). *National Academy of Sciences Diet, Nutrition and Cancer.* National Academy Press, Washington, DC
3 National Institute of Health Consensus Development Panel. (1985). National Institute of Health Consensus development statement on lowering blood cholesterol to prevent heart disease. *JAMA* **253,** 2080–2086
4 American Heart Association. (1978). Diet and Coronary heart disease. *Circulation* **58,** 762A–765A

5 Akoh, C.C. and Swanson, B.G. (1987). One-stage synthesis of raffinose fatty acid polyesters. *J. Food Sci.* **52,** 1570–1576
6 Akoh, C.C. and Swanson, B.G. (1989). Preliminary raffinose polyester and methyl glucoside polyester feeding trials with mice. *Nutr. Reports Intl.* **39,** 659–666
7 Akoh, C.C. and Swanson, B.G. (1989). Synthesis and properties of alkyl glycoside and stachyose fatty acid polyesters. *J. Am. Oil Chem. Soc.* **66,** 1295–1301
8 Akoh, C.C. and Swanson, B.G. (1989). Preparation of trehalose and sorbitol fatty acid polyesters by interesterification. *J. Am. Oil Chem. Soc.* **66,** 1581–1587
9 Akoh, C.C. and Swanson, B.G. (1990). Optimization of sucrose polyester synthesis: Comparison of properties of sucrose polyesters, raffinose polyesters and salad oils. *J. Food Sci.* **55,** 236–243
10 Hamm, D.J. (1984). Preparation and evaluation of trialkoxytricarballylate, trialkoxycitrate, trialkoxyglycerol ether, jojoba oil and sucrose polyester as low calorie replacements of edible fats and oils. *J. Food Sci.* **49,** 419–428
11 Mattson, F.H. and Nolen, G.A. (1972) Absorbability by rats of compounds containing from one to eight ester groups. *J. Nutr.* **102,** 1171–1176
12 Van De Kamer, J.H., Huinink, H.B., and Weyers, H.A. (1949). Rapid method for the determination of fat in feces. *J. Biol. Chem.* **177,** 347–355
13 SAS Institute, Inc. (1986). *SAS User's Guide: Statistics, 1986 Edition.* SAS Institute, Inc., Cary, NC
14 Comai, K., Triscari, J., and Sullivan, A.C. (1978). Differences between lean and obese Zucker rats: The effect of poorly absorbed dietary liquid on energy intake and body weight gain. *J. Nutr.* **108,** 826–835