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Effect of Sun-Dried Raisins on Bile Acid Excretion, Intestinal Transit Time, and Fecal Weight: A Dose–Response Study

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ABSTRACT

The effect of increasing doses of sun-dried raisins (SDR) on intestinal transit time (TT), fecal weight (FW), and fecal bile acids (FBA) was investigated in 16 healthy adults (6 men and 10 women). In three cycles of 2 weeks each, subjects consumed 84, 126, or 168 g/day of SDR. Four-day fecal collections were performed during the second week of each cycle, and TT, FW, and FBA were measured. FW (mean ± SEM), increased from 168 ± 14 g/day without raisins (cycle 1), with a TT of 54 ± 6 hours, to 200 ± 24 g/day with 168 g/day raisins (cycle 4), with a TT of 42 ± 6 hours. Intermediate increases in FW and decreases in TT were observed for cycles 2 and 3. A physiologically meaningful decrease in TT (less than 2 days), to 44 ± 6 hours, was reached at cycle 2 (not statistically significant). FBA, a possible indicator of colon cancer risk, showed a significant decrease, from 1.00 ± 0.18 mg/g wet feces at baseline to 0.38 ± 0.07 mg/g in cycle 2 ($P < .005$), and remained low in cycles 3 and 4. Major decreases were observed in cycle 2 for fecal lithocholic ($P < .02$), deoxycholic ($P < .002$), chenodeoxycholic, and cholic acids, and their concentrations remained low in cycles 3 and 4. Two servings of raisins per day (84 g/day), a relatively small change in diet, can cause beneficial changes in colon function and may decrease the risk for colon cancer.

INTRODUCTION

SUN-DRIED RAISINS (SDR) are a source of both soluble and insoluble fiber and of tartaric acid (Table 1). We previously showed that the combination of dietary fiber and tartaric acid has beneficial effects on intestinal transit time (TT), fecal weight (FW), and fecal bile acid (FBA) composition.[1,2] Grapes and raisins are the only common foods that contain reasonable levels of tartaric acid in temperate climates, tamarind being the other fruit in tropical regions. Tamarind is used in some countries to help normalize bowel function.

Dietary fiber can improve intestinal function by modulating TT, FW, and FBA.[3–5] Possible benefits of decreased intestinal TT and increased FW include wetter stools, which are easier to eliminate,[6] and dilution and hastened elimination of fecal carcinogens.[7] These

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Table 1. Typical Analysis of Sun-Dried Raisins

Constituent	*Content (g/100 g)*
Total dietary fiber*	6.0
Insoluble fiber*	4.3
Soluble fiber*	1.7
Tartaric acid	3.0

*Data on fiber composition vary with method of analysis.

changes are considered protective against colon cancer and other colonic diseases, such as diverticular disease, in addition to helping prevent constipation.

The metabolism of FBA plays a key role in the etiology of colon cancer. Epidemiological and experimental animal studies have shown that the risk for colon cancer increases with increased concentrations of FBA.[8] Dietary fiber has been shown to decrease the concentration of bile acids in the feces.[1,2,9]

The purpose of this study was to determine the effect of SDR on colon function and health by measuring the response to increasing doses of raisins per day after a period free of consumption of raisins and other dried fruits. The key measurements were fecal weight, intestinal TT, and FBA.

MATERIALS AND METHODS

Subjects and study design

Sixteen healthy San Francisco Bay Area adults, age 43 to 80 years old (mean age ± SD, 67 ± 11 years), 10 women and 6 men, who were free from diabetes, cancer, and other major chronic diseases, were placed on a diet free of raisins and dried fruits for 2 weeks (control period, cycle 1). In three successive periods, subjects consumed the following amounts of SDR: cycle 2, 2 × 42 g/day (84 g total); cycle 3, 3 × 42 g/day (126 g total), and cycle 4, 4 × 42 g/day (168 g total). Each cycle lasted 2 weeks, with no washout period between cycles. Gradual increases (42 g per cycle) for each diet treatment were chosen to let the intestinal tract slowly adapt to increases in dietary fiber and tartaric acid from the raisins. Subjects were instructed by a nutritionist to maintain their usual diet, which was discussed with them when each new cycle started. Participants were also asked to complete two food frequency questionnaires, one at the beginning and one at the end of the study, which were reviewed by the nutritionist to ensure that their basic dietary pattern remained unchanged.

TT and FW were measured by collecting feces in special collection containers between Monday morning and Friday morning of the second week of each dietary cycle, allowing 1 week for adaptation to the increased dose of raisins. The fecal sample containers were immediately placed in coolers with ice packs and were kept frozen in the research facility as soon as they were returned by the subjects. Radiopaque pellets were fed on the first day of the 4-day fecal collection period, according to the method of Hinton,[10] and TT was taken as the time required for excretion of 80% of the pellets. FW and TT measurements were performed by X-ray examination of the collected frozen samples in the stool containers. The daily average fecal weight for the 4-day collection period was used in all calculations. All fecal samples were later homogenized, and aliquots were shipped frozen to Purdue University for FBA analyses. These fecal samples were lyophilized, and FBA as trimethylsilyl ether derivatives were extracted and determined by gas–liquid chromatography.

Statistical analysis

Student's paired *t* tests (two-tailed) were used to compare changes in TT, daily FW, and FBA between the raisin-free period (cycle 1) and each SDR period (cycles 2–4). Results are reported as mean ± SEM unless otherwise stated. Results were considered significant at the $P < .05$ level.

RESULTS

Increasing intake of SDR resulted in an increase in FW and a decrease in TT, although the changes did not reach statistical significance (Figs. 1 and 2). FW increased from 168 ± 14 g/day (cycle 1, no raisins), with a TT of 54 ±

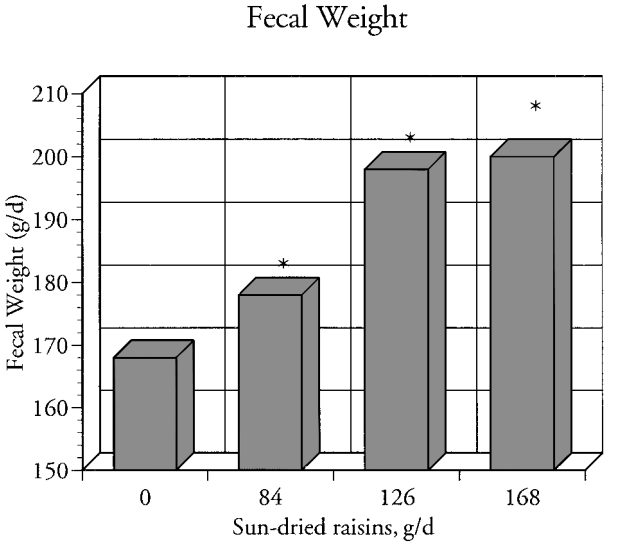

FIG. 1. Mean fecal weight (g/day) for each dose of sun-dried raisins. *Not significantly different from 0 g.

6 hours (more than 2 days), to 200 ± 24 g/day (cycle 4, highest level fed), with a TT of 42 ± 6 hours (less than 2 days). Whereas the addition of 84 g/day of raisins (cycle 2) resulted in changes in both FW (178 ± 16 g/day) and TT (44 ± 6 hours), the addition of another 42 g/day (cycle 3) increased FW (198 ± 18 g/day) but did not further decrease TT (48 ± 6 hours). Fecal percent moisture content was unchanged during all cycles, with 88% fecal moisture for cycles 1, 2, and 3 and 89% fecal moisture for cycle 4.

As shown in Fig. 3, total FBA concentration was significantly reduced by feeding SDR, from 7.88 ± 1.44 mg/g dry feces during the control period (cycle 1) to 2.95 ± 0.45 mg/g when 84 g/day of raisins was consumed (cycle 2; 62% decrease, $P < .005$). No further significant reduction in FBA concentration was observed with additional raisin consumption. Similarly, daily FBA excretion decreased from 170 ± 45 mg/day in cycle 1 to 70 ± 16 mg/day in cycle 2, with no further significant decrease in cycles 3 and 4.

Because FW continued to increase with increasing raisin consumption, we determined the concentration of FBA per gram of wet feces (Fig. 3). Results were similar to those observed in relation to dry fecal weight, with a significant decrease, from 1.00 ± 0.18 mg/g wet feces in cycle 1, to 0.38 ± 0.07 mg/g in cycle 2 (62% decrease, $P < .005$), and no further decrease in cycles 3 or 4. As shown in Fig. 3, the decrease in total FBA concentration was due mainly to major decreases for both lithocholic acid ($P < .02$) and deoxycholic acid ($P < .002$).

DISCUSSION

We observed beneficial changes in colon function when subjects were given two servings of SDR (84 g total) per day, including a decrease in TT to less than 2 days (−19%) from 54 hours during the raisin-free period. Three servings of SDR (126 g) per day increased fecal weight (+18%) and resulted in stools that were easier to eliminate. Four servings (168 g) per day further decreased TT to 42 hours (−22%) and increased fecal weight to 200 g/day (+20%). These findings confirm the results of our previous study,[1] in which consumption of three servings of SDR (120 g) per day for 3 weeks was shown to increase FW by 34% (177 g/day), compared with a low-fiber, raisin-free period (132 g/day), and to cause a 33% reduction in TT (from 42 hours at baseline to 28 hours). Although the changes in FW and TT in our previous study[1] were of greater magni-

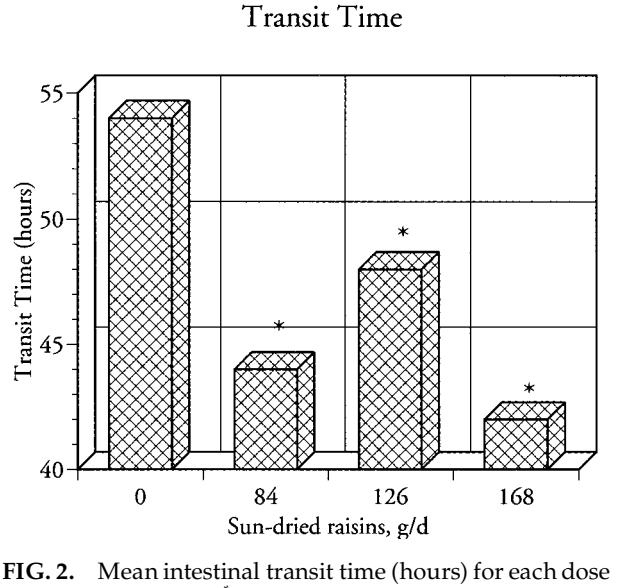

FIG. 2. Mean intestinal transit time (hours) for each dose of sun-dried raisins. *Not significantly different from 0 g.

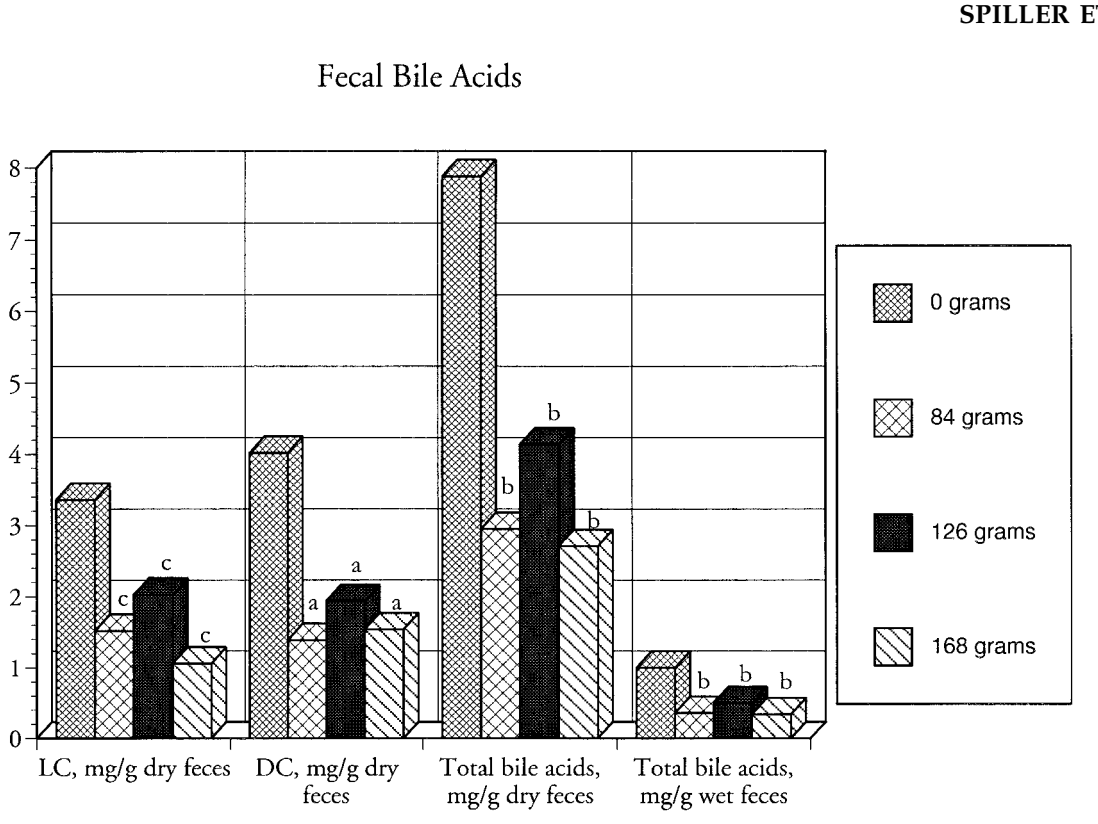

FIG. 3. Mean fecal bile acids for each dose of sun-dried raisins. [a]Significantly different from 0 g, $P < .002$; [b]significantly different from 0 g, $P < .005$; [c]significantly different from 0 g, $P < .02$; LC, lithocholic acid; DC, deoxycholic acid.

tude, we found in the present study that a physiologically meaningful reduction in TT, to less than 2 days, can be achieved with only two daily servings of SDR (84 g/day). This finding is very encouraging, because this relatively small alteration in diet can cause a significant change in TT, helping to prevent constipation and, possibly, to protect against diseases of the colon, such as diverticular disease and colon cancer.[7]

Two daily servings of SDR was also found to significantly decrease the total FBA concentration (−62%), a factor that has been linked with the etiology of colon cancer.[9] Previously, we showed that three daily servings of SDR (120 g/day) significantly reduced the total FBA concentration (−23%).[2] Again, this finding suggests that only two servings of raisins per day could beneficially alter FBA concentration in a way that is considered protective against colorectal cancer.[8]

The results of this study, together with our previous findings, make a strong case for recommendations to the public to increase the use of foods with specific effects on disease risk factors and to combine foods that have beneficial effects (e.g., raisins) with a diet high in whole grains. Whole-grain raisin bread was shown in a previous study[11] to help normalize colon function, but this effect was measured by questionnaire only.

In conclusion, SDR, at a dose of 84 g/day, can beneficially alter colon function in a way that may at help prevent constipation and, possibly, protect against diseases of the colon and colorectal cancer. More research is needed to investigate the effect of the combination of raisins with whole grains, nuts, and other whole plant foods that are high in fiber.

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