THE NUTRIENTS AND BIOACTIVES OF PECANS: A POTENTIAL MARKETING TOOL?

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INTRODUCTION

The pecan [*Carya illinoinensis* (Wangenh.) K. Koch] is a monoecious, heterodichogamous, deciduous nut tree that is indigenous to the U.S. (*1*). This specialty crop is economically important to the U.S. as it accounts for > 80% of the world's production (*2*). Six states constitute > 90% of the U.S. crop and include Georgia, Texas, New Mexico, Oklahoma, Arizona, and Alabama. Georgia is the largest producer with 10^{+} commercially-viable cultivars including Cape Fear, Curtis, Desirable, Elliot, Gloria Grande, Kiowa, Oconee, Pawnee, Schley, Stuart, and Sumner. Of these cultivars, Stuart and Desirable pecans are economically the most important ones. From 1999 to 2005, the annual pecan production in the U.S. ranged from 173 to 400 million pounds (in-shell) with an estimated market value of $201 to 407 million (*3*).

PECAN CLINICAL STUDIES

According to the American Heart Association, cardiovascular disease (CVD) was responsible for 35.2% of all deaths nationwide in 2005 with heart disease remaining as the number one killer in the U.S. (*4*). Epidemiologic studies have consistently demonstrated an inverse association between nut consumption and risk markers of coronary heart disease (CHD) (*5,6*). In relation to individuals who ate nuts < one time/wk, those who ate them one-four times/wk had a 25% reduced risk of dying from CHD; individuals who ate nuts ≥ five times/wk experienced a ~50% reduction in risk (*7*). The Food and Drug Administration (FDA) was eventually petitioned and approved a qualified health claim with the following statement: "*Scientific evidence suggests, but does not prove, that eating 1.5 ounces per day of some nuts, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease.*"

A number of mechanisms exist as to why nuts, such as pecans, impart favorable effects on our cardiovascular system; the most important one being the lipid-lowering in blood serum. Yet, the lipid effects of nut intake only explain in part the CHD risk reduction observed in prospective studies. Pecans are low in saturated fatty acids and rich in the monounsaturated fatty acids (MUFA), particularly oleic acid, which is known for its positive effects on blood lipids (*8*). In fact, the MUFA levels in pecans are similar to those of olive oil. The Scientific Advisory of the American Heart Association reported that high MUFA diets tend to raise high-density lipoprotein (HDL) cholesterol and lower triacylglycerols (TAG) concentrations compared with low fat carbohydrate-rich, cholesterol-lowering diets; this has the benefit of reducing the process of atherosclerosis and hence the risk of CHD. Evidence further suggests that other components in pecans further reduce total cholesterol and low-density lipoprotein (LDL) cholesterol concentrations beyond the effects predicted by equations based solely on fatty acid profiles. Pecans are also rich in antioxidant vitamins, minerals, and numerous bioactives including flavonoids, stilbenes, and phytosterols that may have health benefits. Kris-Etherton *et al.* (*5*) pointed out that it is conceivable, though not proven, that many nutrients and bioactives in nuts, like pecans, may act synergistically to exert beneficial effects in the human body.

There have been four significant dietary studies about the effects of pecan consumption on serum (blood) lipid profiles. The first, a randomized control study from New Mexico State University compared the serum lipid profiles and dietary intakes of individuals with normal lipid levels (*i.e.,* normolipidemic) who consumed pecans and those who did not eat any nuts (*9*). The pecan treatment group consumed 68 g pecans per day for eight weeks plus "self-selected" diets, whereas the control group avoided pecans plus other nuts and also consumed "self-selected" diets. What is most interesting about this study, is that though there is variability in the dietary habits of food choices made and calories consumed on a daily basis, this approach represents perhaps a realistic appraisal of the impact of pecans set forth in the FDA qualified health claim for tree nuts. Total, LDL, HDL, and TAG levels were measured at the onset of the study to offer baseline data, again at week four and then finally at week eight. Results showed that LDL cholesterol was lowered in the pecan treatment group from 2.61 ± 0.49 mmol/L at baseline to 2.35 ± 0.49 at week four ($P < 0.05$) and to 2.46 ± 0.59 at week eight ($P < 0.05$). For the control group, LDL cholesterol levels increased from 2.74 ± 0.26 mmol/L at week zero to 3.03 ± 0.57 at week eight. In terms of total cholesterol and HDL cholesterols, the numbers for the pecan treatment group at week eight were significantly ($P < 0.05$) lower than in the control group (total cholesterol: 4.22 ± 0.83 vs 5.02 ± 0.54 mmol/L; HDL cholesterol: 1.37 ± 0.23 vs 1.47 ± 0.34 mmol/L). Additionally, dietary fat, MUFA, polyunsaturated fatty acids (PUFA), insoluble fiber, magnesium, and energy were significantly higher in the pecan treatment group than in the control group. Body mass indices and body weight were unchanged in both groups. Morgan and Clayshulte (*9*) concluded that pecans can be included in a healthful diet when energy intake and potential weight gain are addressed.

The clinical study from New Mexico State University might be the first published study to specifically examine the effects of pecan ingestion on blood cholesterol and TAG levels. Even though the study involved only 19 people, its findings are supportive of the FDA qualified health claim for nuts and heart disease prevention. A study from Loma Linda University published in 2001 confirmed and extended the findings put forward by Morgan and Clayshulte (*9*). The study by Rajaram *et al.* (*10*) incorporated strict dietary regiments to control nutrient intake in addition to pecan supplementation. This study examined the effects of pecan lipids as an alternative to the American Heart Association's Step I diet (*i.e.*, a diet recommended by the National Cholesterol Education Program to lower cholesterol). Although the Step I diet is deemed favorable due to its relatively high carbohydrate and low fat contents, it has the disadvantage of tending to lower HDL cholesterol and raise TAG levels in the blood serum: an undesirable characteristic. Rajaram *et al.* (*10*) designed a single-blind, randomized, controlled, crossover feeding study for 23 subjects to follow two diets each of four weeks: a Step I diet, and a pecan-enriched diet (72 g per day) which proportionately reduced all food items of the Step I diet by one fifth to provide a 20% isoenergetic replacement with pecan. Both diets improved lipid profiles of the subjects. The pecan-enriched diet decreased both total and LDL cholesterol concentrations by 0.32 mmol/L (*i.e.*, 6.7 and 10.4%, respectively) and TAG by 0.14 mmol/L (~ 11.1%) beyond the Step I diet, while increasing HDL cholesterol by 0.06 mmol/L. Furthermore, other serum lipoprotein markers decreased (a good thing!) as a result of pecan supplementation to the diet. The authors concluded that pecans, which are rich in MUFA, may be recommended as part of a prescribed cholesterol-lowering diet for patients or as part of the diet for healthy individuals. They also postulated that the unique non-fat component of pecans (*i.e.*, phytochemicals with noted antioxidant activity) may also play a role in favorably modifying the blood lipid profile and potentially other cardiovascular risk factors.

In 2005, a second clinical study on the potential health benefits of pecan consumption from New Mexico State University was published (*11*). An eight-week, randomized, controlled study was conducted to assess the effect of pecan supplementation to the diets of hyperlipidemic adults (*i.e.*, all 17 participants had total plasma cholesterol > 200 mg/dL and LDL cholesterol > 130 mg/dL). Again as in their previous study, individuals were assigned to a control group with no nut consumption or to a group where 68 g of pecan were consumed daily over the eight-week trial. All other aspects of the diet were self-selected. The researchers wanted to determine whether a significant effect on blood lipids would be found with a smaller (*i.e.*, 68 g/day) and possibly a more dietarily acceptable level of nut supplementation. The results suggested that the inclusion of pecan in the diets of hyperlipidemic individuals only had a transient influence on the total and LDL cholesterol profiles, and did not yield sustainable lipid-lowering effect when total dietary fat intake was not limited. The researchers suggested that the 45 to 48% of energy as fat in the self-selected diets of the hypercholesterolemic participants consuming pecans might have been a mitigating factor in the transient lowering than raising of total and LDL cholesterol levels. What is most interesting is, if the study had been concluded after four weeks instead of eight pecan consumption would have appeared to exert a lipid-lowering effect (Table 1). Despite the lack of a sustained lipid-lowering effect, the authors recommended the inclusion of modest amounts of pecans as part of a healthy diet because of their overall nutritional profile.

THE NUTRIENTS AND BIOACTIVES OF PECANS

The proximate compositions for both raw and dry roasted pecans are given in Table 2 (*12*). In addition to MUFA, emerging evidence indicates there are other bioactive molecules in nuts, such as pecans, that elicit cardioprotective effects. These include plant proteins, dietary fiber, micronutrients such as copper, zinc, and magnesium, plant sterols, and last but not least phytochemicals (*13*). Pecans are an excellent source of tocopherols, particularly γ-tocopherol (*14*). Emerging research suggests that γ-tocopherol does not get the respect it deserves as a nutrient. γ-Tocopherol may have unique functions in detoxifying nitrogen dioxide and other reactive nitrogen species (*15*). The phytochemicals in pecans account for a portion of the nut's observed antioxidant and radical-scavenging capacities. The antioxidant activity originates mostly from the phenolic constituents (*e.g.*, phenolic acids and tannins) and tocopherols. Early studies by Senter *et al.* (*16*) from the testa of Stuart pecan kernels revealed the presence of gallic, gentisic, vanillic, protocatechuic, *p*-hydroxybenzoic, and *p*-hydroxyphenylacetic acids, with coumaric and syringic acids present in trace amounts. Phenolic acid levels decreased markedly in the kernels during 12 weeks of accelerated storage. Strong correlations (r^2 = 0.95 to 0.97) were obtained between decreases in the hydroxybenzoic acid derivatives and declines in sensory quality of the kernels, thereby suggesting that these phenolic compounds may function antioxidatively and provide stability during storage. In a more recent study, Villarreal-Lozoya *et al.* (*17*) analyzed six pecan cultivars and found strong correlations in the kernels between total phenolic content and antioxidant activity. The total phenolic content ranged from 62 to 106 mg chlorogenic acid equivalents/g defatted kernel and was significantly affected by pecan cultivar. These findings as well as on-going nutrient and bioactive research in Dr. Pegg's lab confirm the presence of hydrolyzable tannins in the pecan kernels: both gallo- and ellagitannins types.

In a report that screened common foods and vegetables across the U.S., pecan kernels were shown to have the highest antioxidant capacity and total extractable phenolic content within the nut group, and pecans ranked amongst the foods with the highest phenolic content (*18*). The cultivar of the sample was, however, never identified. Both oxygen radical absorbance capacity ($ORAC_{FL}$) and 2,2′-diphenyl-1-picryhydrazyl (DPPH) radical data on defatted kernels show marked radical-scavenging capacity and strong correlations between these antioxidant assays with total phenolics; mean $ORAC_{FL}$ values for the different pecan cultivars ranged from 373 to 817 µmol Trolox equivalents/g defatted meal. Finally, there is a growing body of evidence that polyphenols can facilitate circulatory function through increased production of the primary mediator of endothelial dilatation, viz. nitric oxide (*19*). Maintaining the func-

Table 1. Effects of a pecan-enriched diet on plasma cholesterol in hyperlipidemic adults.[a]

Serum lipid values mg/dL (mmol/L)	Weeks of supplementation 0	4	8
Total cholesterol			
Control group	259 ± 64 (6.71 ± 1.66)	257 ± 60 (6.66 ± 1.55)*	258 ± 67 (6.68 ± 1.74)
Pecan treatment group	233 ± 19 (6.03 ± 0.49)	221 ± 18 (5.72 ± 0.47)*	232 ± 35 (6.01 ± 0.91)
LDL cholesterol			
Control group	171 ± 60 (4.43 ± 1.55)	173 ± 60 (4.48 ± 1.55)**	169 ± 64 (4.38 ± 1.66)
Pecan treatment group	152 ± 21 (3.94 ± 0.54)‡	136 ± 22 (3.52 ± 0.57)**†	153 ± 33 (3.96 ± 0.85)†
HDL cholesterol			
Control group	52 ± 12 (1.35 ± 0.31)	55 ± 13 (1.42 ± 0.34)	56 ± 16 (1.45 ± 0.41)
Pecan treatment group	45 ± 11 (1.17 ± 0.29)	46 ± 12 (1.19 ± 0.31)	42 ± 18 (1.09 ± 0.47)
TAG			
Control group	183 ± 84 (2.07 ± 0.95)	143 ± 54 (1.62 ± 0.61)	160 ± 78 (1.81 ± 0.88)
Pecan treatment group	205 ± 122 (2.32 ± 1.38)	204 ± 123 (2.31 ± 1.39)	221 ± 173 (2.50 ± 1.95)

[a] Data adapted from Eastman and Clayshulte (*11*); values reported as group means ± standard deviations. n = 9 for the control group and n = 8 for the pecan treatment group.

*$P < 0.05$, **$P < 0.01$, significant difference between groups (ANOVA).

†$P < 0.05$, ‡$P < 0.01$, significant difference over time within group (ANOVA).

Table 2. Proximate composition (g/100g) of raw and dry roasted pecans.[a]

	Raw	Dry roasted
Water	3.52	1.12
Total Lipid	71.97	74.27
Protein	9.17	9.5
Ash	1.49	1.56
Carbohydrate	13.86	13.55
Fiber, Total Dietary	9.6	9.4

[a] USDA National Nutrient Database for Standard Reference, Release 22 (*12*).

tional capacity of the endothelial cells lining blood vessels is vital to vascular health. Improvements in endothelial vasodilator function have been reported with high nut consumption (*20*).

CONCLUSIONS

Pecan consumption can play a significant role in human nutrition and health on account of its high and special nutritional components. Marketers should take advantage of the FDA qualified health claim for nuts in tandem with the nutrient and bioactive contents found in present day pecan cultivars. These nutritional attributes clearly indicate that pecans can serve as an important healthy food in the human diet and should be consumed every day. With respect to functional lipid characteristics of pecans, they are good sources of natural antioxidants (*e.g.*, γ-tocopherol) and bioactives, thus reflecting their nutraceutical potential in different food and specialty applications. Despite an increase in dietary fat content, pecan-enrichment as part of a healthy diet favorably affects plasma LDL and HDL cholesterol levels as well as lipoprotein profiles, major risk factors of CVD. A high MUFA-rich pecan diet is preferred to a low-fat control diet in decreasing plasma LDL cholesterol concentrations. The presence of essential minerals, vitamins, and amino acids, the high content of heart-healthy fats, and the presence of soluble dietary fiber, bioactives, and phytochemicals, including their antioxidant and radical-scavenging capacities, make the choice of pecan addition to healthy diets an important dietary consideration in assisting against the potential development of chronic disease states.

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