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CONSUMER SENSORY EVALUATION OF PECANS

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ABSTRACT

A review of research activities over several years of sensory evaluation of pecans and supercritical fluid extraction (SFE) of pecan oil using supercritical CO_2 has lead to the following observations and conclusions:

- The SFE nut kernels differ in sweetness (more), nutty/oily flavor (less), internal color (whiter), and texture (more chalky or pithy) as compared to non-extracted pecans.
- There is no difference in acceptability between the extracted and non-extracted pecan kernels.
- The SFE adds weeks to shelf life and reduces fat calories by 20 – 30%.
- Packaging at low oxygen levels is not as effective as SFE in extending shelf life.
- SFE causes damage to the internal tissues of the kernels, but this is largely mitigated by slow pressure release.
- The extracted pecan oil is a good, heart healthy product that has many nutritious and gourmet applications.
- The flavor and texture of SFE pecans are similar to non-extracted improved varieties.
- Hexanal level is a good test for the measurement of rancidity in pecans.

Current research efforts with SFE of pecans center on whether other extracting gases yield similar results as to both flavor in the kernels or selectivity of fatty acids in the oil and on development of new uses and markets for pecan oil.

First Sensory

Our first attempt at sensory evaluation of pecans was several years ago working with an Elderhostel group who were experiencing various educational activities at Oklahoma State University. One of those activities was participating as panelists in sensory evaluation. These panelists ranged in age from 55 to 70 and were retired business and professional men and women. None reported being pecan consumers, coming primarily from northern states. They participated in paired comparison testing to determine whether they could tell the difference between Oklahoma native pecans and a large improved variety pecan. They were also asked to describe any differences they detected and rate acceptability. They had no trouble detecting a difference ($p<0.01$), and several reported that the native had a nuttier, oilier taste and the improved variety had a more open, pithy texture. However, the two were rated as being equally acceptable; and, based on plate waste data, found both varieties very acceptable, since the panelists consumed all of both samples.

Hexane Extraction

In cooperation with the Oklahoma Pecan Growers Association, the Nutritional Sciences Department at O. S. U. entered into research to develop a method to reduce the fat level in intact pecan pieces (Waters, 1985). Following procedures similar to those used to extract oil from cottonseed meal, pecan halves were prepared with some left intact and some chopped into different specific particle sizes. Sensory evaluation showed the extracted pecans as having a sweet nutty flavor, with a lighter interior, and an overall rating that was more acceptable than the control pecans. Of the pecans that were chopped, the larger pieces were more acceptable than the ones that were chopped fine, and the finer the chop, the more oil was extracted (15 – 40%). The oil was a nice, pale yellow fluid that was remarkably stable and remained good tasting with a minimum of refinement for many months if kept under refrigeration. This research established that partial fat removal did not diminish acceptability of the kernels and yielded a second product, the pecan oil. The next step would be to determine the effect on shelf life. However, there was a greater residue of hexane remaining in the nuts than proposed FDA rules would allow, so another means of extraction was sought, preferably one that would not present the problem of using explosive compounds. Investigation of supercritical CO_2 as the extracting medium seemed to be a logical choice.

Need for an Objective Test

In related research, Waters (1992) conducted a survey of members of the Oklahoma Restaurant Association to determine if restaurant managers or purchasing agents knew how to determine whether a quantity of pecans was of acceptable quality before taking delivery, and how to maintain quality in the pecans they purchased until use. She found that most of the respondents knew how pecans should be stored, although many did not practice good storage procedures. Additionally, though they were quick to refuse a shipment for obvious carton damage or

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evidence of insect infestation, they did not trust their own judgement to determine whether a pecan was of poor quality due to development of off flavors and rancidity. These findings demonstrated the need for an objective test that would accurately reflect sensory characteristics of pecans.

CO_2 Supercritical Fluid Extraction
CO_2 is environmentally friendly, not explosive, and at the right combination of temperature and pressure becomes a fluid having the oil extracting characteristics of both a liquid and a gas. In interdepartmental research, supported by the State of Oklahoma (OCAST) as well as the departments and colleges involved, a series of three experiments was performed. The first was to determine the parameters for using SFE to extract oil and test the effect of the extraction procedure on subjective and objective characteristics of the pecan kernels. The second was to test the effects of SFE on shelf life of pecans. The third was to test the effects of oxygen levels in packaging on the shelf life of SFE pecans. The departments involved in the research were Horticulture and Landscape Architecture, Biosystems and Agricultural Engineering, and Nutritional Sciences at Oklahoma State University. (Maness, et al, 1995; Maness et al, 1997)

Study I: Effect of SFE on Pecan Flavors
This research had two goals: to determine how flavors and texture changed under different extraction conditions of time and temperature, and to help in setting the parameters for SFE extraction (Chinta, 1998).

Seventeen graduate students enrolled in a research methods course were recruited as panelists. After training in basic flavors, the panelists were trained in pecan flavor and texture attributes. During testing, the panelists rated pecans extracted at 40°C and 80°C for a variety of times.

Significant differences were identified in all attributes measured ($p<0.05$). The extracted pecans had a whiter interior, sweeter taste, less nutty/oily and roasted flavors, and a texture that was less crisp but more "woody". In spite of detecting these differences, there was no significant difference in acceptability between the extracted and non-extracted kernels.

Through this testing, it was determined that in terms of both fat extraction and effect on the pecans, there was no merit in extracting for more than 20 minutes or at a temperature above 40°C.

Study II: Effect of SFE on Shelf life
This study also had two objectives. One was to determine if SFE would extend shelf life. The other was to see if a chemical test could accurately detect early stage rancidity (Chinta, 1998).

Pecans were extracted (see Table 1) at 40°C for 20 minutes (22% oil removal) and at the same temperature for a longer time - 480 minutes (28% oil removal). The extracted nuts and non-extracted controls were packaged in small bags, each holding about 15 grams of sample. These bags were vacuumed, then backflushed with a generated pure 21%/79% O_2/N_2 atmosphere and held at 25°C for 32 weeks. This followed a 3x10x3 factorial design with three replications that were treated as blocks.

Table 1. CO_2 SFE Extraction conditions

SFE Dionex[R] 703 Extractor
Final pressure: 69 Mpa Flow rate: 510 – 680 ml/min

Table 2. Hexanal Determination

Headspace gas GC Split injector (ratio 1:50) FID detector DB-23 Silica capillary column
Injector temperature: 275°C Detector temperature: 300°C

The small, 40 ml volume of the extraction vessel and the necessity of keeping samples for objective chemical testing presented a challenge to the researchers. Accumulating a large volume of sample material was difficult and the amount to be used for sensory evaluation had to be distributed into packets for evaluation over a 37-week period with three replications. Therefore, only a small amount was available for each sensory testing session. Recognition of this limitation resulted in a select group of four panelists being trained in specific pecan flavor characteristics (see Table 3). The original design was for the experiment to continue for 37 weeks. However, by the end of the 32nd week, one of the treatments was so strong in rancid flavors, further testing was discontinued.

There were initial sensory differences in the 3 oil levels (full fat, 22% reduction, and 28% reduction). The extracted pecans had a lighter (whiter) interior possibly due to the removal of the yellow colored pecan oil. The non-extracted pecans were the most crisp and the 28% fat reduced were the least crisp. The non-extracted pecans were rated as least chalky, and the 28% fat reduced were rated as most chalky. The non-extracted pecans were oilier than either the 22% or the 28% fat reduced pecans. Non-extracted pecans also had a less toasted flavor than either the 22% or the 28% fat reduced pecans.

Table 3. Pecan flavor characteristics

Color	Testa Interior
Texture	Chalky Woody Crispness
Pecan flavor	Sweet Nutty Oily
Off flavors	Tannin Sour Rancid Toasted
Overall acceptability	

Table 4. Comparison of Fatty Acid Profiles (grams / 100 g of oil) (%)

Oil	Sat. Fat	MUFA	PUFA
Pecan	8	62	28 [1]
Peanut	17	45	32 [2]
Olive	14	74	8.4 [3]

[1] *24 as linoleic*
[2] *all as linoleic*
[3] *7.9 as linoleic*

There were also flavor changes over time. The perceived oiliness increased in the non-extracted (full fat) pecans during the last three months of the study (after week 18). Rancidity, similar to perceived oiliness, increased in the full fat pecans during the last three months as well. In one of the full fat replications there was, in fact, a significant increase in rancid flavors between weeks 10 and 14. Also, there was a decline in acceptability after week 18.

There were very few changes over time in either of the SFE pecan extraction levels with samples showing neither increasing rancidity nor decreasing acceptability during the entire course of the study. One of the replications in the 22% reduction level actually increased in acceptability between weeks 10 and 14.

Conclusions were that SFE extraction significantly extended the non-refrigerated shelf life of the pecans. Further, there is no merit in reducing oil beyond 22% in order to extend the shelf life.

Hexanal production was affected by storage time in agreement with Forbus et al. (1980). Hexanal levels ranged from 0 to 16.99 ppm for the full fat (0 extracted) pecans; 0 to 4.44 ppm for the 22% reduced oil pecans; and 0 to 0.56 ppm for the 28% reduced oil pecans during the 32 weeks of storage. Significant levels of hexanal were not detected in any treatments until the 22nd week of storage, when the hexanal in the non-extracted nuts showed an increase, rising above the 6ppm that Hofland et al. (1995) associated with undesirable flavors. At no time did the extracted pecans reach this level, strongly indicating that a low hexanal level could be used as an objective test for presence of rancidity in pecans.

Study III: Effect of Oxygen Concentration on Storage

Delaying oxidative reactions by reducing the oxygen in the storage package appears to be a logical way to preserve pecan quality during non-refrigerated storage. However, a low level of oxygen is necessary to retain normal metabolic activity in the nuts. This level is thought to be in the 2% range (Kays, 1991). Pecans were extracted at 40°C for 20 min. to a oil reduction level of about 22%. This study utilized two extraction levels (0 and 22%), three oxygen levels (2%, 10%, and 21%), over five storage time periods (0, 3, 6, 9, and 12 months). (Chinta, 1998) The pecans were maintained at 25°C and 55% relative humidity in dark storage. Due to the small sample size available for sensory evaluation, the same four panelists used in Study II were utilized for this study and they used score sheets similar to those in Study II. This was a 2x3x5x3 factorial experiment with alpha level of $p=0.05$, with three replications that were treated as blocks.

There were significant differences in internal color of the pecans. The non-extracted pecans became darker over time, whereas the extracted pecans became lighter. However, these differences were not due to oxygen level. Rancidity scores rose after 6 months at all oxygen levels, but were highest at the 2% level. Also, rancidity scores rose between 6 and 9 months for both the extracted and non-extracted pecans. Acceptability scores for both treatments dropped over time with the lowest scores tending to be after 9 months, but the rate of decline was slower for the extracted pecans.

For this study, the conclusions were that time had a greater impact on development of rancidity than did oxygen level. For all samples acceptability scores declined over time but the rate of decline was slower for the extracted pecans.

Other Research
Electron microscope studies (using both scanning and transmission microscopy) of the SEF pecans showed that extraction was quite disruptive to the internal tissues, and that greater pressure resulted in greater damage. However, there was less damage in pecans extracted in a commercial SEF unit that in the laboratory sized unit. Apparently the larger extraction vessels produce a more uniform, less damaged product. Further, the internal tissue damage could be largely mitigated by releasing pressure slowly. However, the woody or chalky texture the panelists reported in the extracted pecans was probably a manifestation of the tissue disruption. (Knight, et al, 1998)

In recently completed interdepartmental research, a comparison was made regarding flavor changes over time in peanut varieties with three different oleic/linoleic acid ratios. In that study, Watson (1998) found that all three varieties developed rancid-type off flavors, and that the off flavors in the variety with the highest linoleic acid concentration were those best detected by the GC hexanal test. This supports our conclusion from Study II above, and that it is the breakdown of the linoleic acid in the pecans that was responsible for the rancid flavor reported by the pecan panelists.

About the Extracted Pecan Oil
The pecan oil generated through SFE is a light yellow colored oil similar in appearance to corn oil. It is very high in oleic acid (64%), almost as high in this "heart-healthy" monounsaturated fatty acid as olive oil (see Table 4). However the very pleasant flavor of the pecan oil is much more compatible with many types of food than is olive oil. We are currently preparing a variety of foods, cakes and other baked goods, desserts, salad dressings, and gourmet applications for this oil. Also, functional properties of the oil, such as smoke point, should be determined. Our research has also determined that a doughnut fried in pecan oil "is to die for." Pecan oil is quite stable. Although non-refrigerated storage studies have yet to be done, we do know that it keeps indefinitely refrigerated, even if unrefined.

Current Research
Supercritical CO_2, although environmentally friendly and non-explosive, requires pressures of 10,000 psi or more for extraction. Other hydrocarbon gases, when super critical, are also FDA approved for food uses and require pressures of 200 psi or less. Although they do not have all the advantages that CO_2 enjoys, the lower pressure requirements can make such extraction more economically friendly. Therefore, studies are beginning to determine whether these other SFE gases yield similar results as to both flavor and shelf life extension and whether any of these offer any selectivity of extracted fatty acids.

Nutritional Science researchers who have contributed to the information presented in this review include:
Marilyn Waters
Bhaggi Chinta Emani
Debesu Tideg
Jack Huang
Anu Srireddy
Faye Watson

Literature Cited

Chinta, B., 1998. The Effect of Supercritical Fluid Extraction on the Shelf Life and Structure of Pecans, Ph.D. dissertation (in preparation), Oklahoma State University, Stillwater, OK.

Forbus, W.R. Jr., Senter, S.D., Lyon, B.G. and Dupuy, H.P., 1980. Correlation of objective and subjective measurements of pecan kernel quality. J Food Sci. 45(4):1376-1379.

Hofland, C., Vickers, Z. and Fritsch, C.W., 1995. Sunflower kernel shelf life study. Effects of temperature, packaging and roasting oil on storage flavor. Presented at Ann. Mtg., Inst. of Food Technologists, Atlanta, GA, June 25-29.

Kays, S.J., 1991. Post harvest quality. In Wood, B.W. and Payne, G.A. (eds.) Pecan husbandry: challenges and opportunities. First National Pecan Workshop Proceedings, USDA ARS-96, p. 194-228.

Knight, S., Chinta, B., and Baker, G., 1998. The effect of supercritical fluid extraction (SFE) on the structure of pecans. So. Assn. Agri. Sci., Abst. 29, 1998.

Maness, N., Smith, M. W., Brusewitz. G., and Knight, S., 1997. Pecan oil reduction for enhancing markets. The Pecan Grower, VII(4):2, 3.

Maness, N.O., Chrz, D., Pierce, T., and Brusewitz, G.H., 1995. Quantitative extraction of pecan oil from small samples using supercritical carbon dioxide. J. Amer. Oil Chem. Soc., 72:665-669.

Waters, M.B., 1985. Partial Extraction of Oklahoma Pecans, MS thesis, Oklahoma State University, Stillwater, OK.

Waters, M.B., Knight, S.B., and Warde, W.D., 1992. Pecan purchasing and handling practices of food service operators. So. Assn. Agri. Sci., Abst. 44, 1992.

Watson, F.A., 1998. A Comparison of Roasted Peanut Flavor Attributes Over Time for Three Peanut Cultivars with Divers Oleic:Linoleic Acid Ratios, MS thesis, Oklahoma State University, Stillwater, OK.