J Sci Food Agric **84**:105–111 (online: 2003)
DOI: 10.1002/jsfa.1593

Note on utilisation of peanut seed testa†

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Abstract: Peanut testae (skins, seed coats) are an extremely low value by-product of peanut-blanching operations. Their commercial value is $12–20 per ton and their limited use is only as a minor component of cattle feed. Based on world in-shell peanut production of 29.1 million tons in 1999/2000 and an average skin content of 2.6%, world production of peanut skins can be estimated at over 750 000 tons annually. Research performed to find new uses for peanut skins demonstrated that up to 35% of the oil in the skins can be recovered. In some cases the oil can be a new potential source of behenic and lignoceric acids, which are used in body-building formulations and as ingredients in shampoos. After removal of the oil the skins were useful for making brandy, liqueur and tea. Peanut skin oil extraction followed by tannin extraction also produces a protein-enriched product that could find application in mixed feeds for cattle consumption at higher concentrations relative to existing practice. A simple technique was also offered to use the skins in finishing decorative panels.
Published in 2003 for SCI by John Wiley & Sons, Ltd.

Keywords: peanuts; *Arachis hypogaea*; peanut testa; peanut oil; lignoceric acid; behenic acid; antioxidants

INTRODUCTION

Roasted peanut (*Arachis hypogaea* L) seeds are a desirable food product with a pleasant and unique flavour. On a worldwide scale, peanuts are grown primarily for their seed oil, which is favoured for cooking and as a salad oil. Peanuts attract attention as a source of protein as well,[1] since there is a growing demand throughout the world for more protein supplies and balanced dietary sources of protein. Peanut skins being produced in hundreds of thousands of tons annually as a by-product of the peanut industry still do not have any significant use.

Peanut skins (testas, seed coats) consist of skins from processed peanuts, broken nuts and, sometimes, nuts that may have been rejected during the preparation of peanuts for human consumption. Peanut skins are known to contain some fat, salt and 16–18% crude protein.[1] Peanut skins were demonstrated to contain beneficial flavanols and to be free of compounds that are toxic to animals (http://users.aol.com/lpluby/history.htm). Since peanut skins contain fairly high levels of tannins and are a lower-energy by-product, they are limited to about 5–8% of the ration of dairy cattle. Tannins act in the gut by binding dietary protein and making it unavailable for digestion or absorption.

Peanut oil contains a high level of unsaturated lipids susceptible to oxidation, as indicated by its relatively high iodine value and refractive index.[1] About 96% of peanut triglycerides are composed of palmitic, stearic, oleic and linoleic acids. The fatty acid composition of peanut oil is influenced by cultivar, maturity stage and environmental conditions. The mature seed contains more stearic and oleic and less arachidic, behenic and lignoceric acids than the immature seed.[2]

The oleic/linoleic (O/L) ratio as an indicator of oil stability (oven-keeping time at 60 °C) was postulated by several researchers.[3,4] Higher O/L ratios indicate more stable oils. The relative linoleic acid content of peanut oil was found to be among the major factors affecting oil stability. Oils from seeds of various peanut cultivars differ in their tendency to develop oxidative rancidity or undesirable odours and flavours. Virginia market types, for instance, produce oil with a lower linoleic percentage and therefore greater stability.[4]

Peanut storage is important both to production agriculture and to product utilisation. Seeds are usually stored for 6–9 months from harvest to planting time. During this storage period, quality must be maintained to allow the production of safe, desirable products. Carbonyls, peroxides, free fatty acids and other quality factors indicated that quality decreased with storage time and higher moisture levels in the storage facilities.[5] Peanut seeds (shelled or unshelled) deteriorate quickly in unfavourable storage conditions (high humidity and high temperature). Peanuts are relatively short-lived in storage.[5]

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(*Received 12 April 2001; revised version received 24 July 2003; accepted 19 August 2003*)

The colour of raw peanut skins is attributed to tannins and catechol-type compounds. The characteristic colour of roasted peanuts is due primarily to sugar–amino acid reactions with subsequent production of melanins.[6] The brown colour development intensifies as the temperature of roasting increases or as the roasting time increases. To some degree, similar changes are expected of peanut skins. Consumption of peanuts as nuts is based exclusively on the use of roasted peanut seeds, so knowledge of the chemical changes in peanuts and skins is critical.

In anticipation of changes in economic conditions to improve the competitive position of peanuts as a source of protein, efforts to develop appropriate food applications for their utilisation should be expected.

The purpose of this work was to develop approaches for the utilisation of peanut skins.

EXPERIMENTAL

Peanut and peanut skin sources

Peanut skins and kernels of *A hypogaea* were obtained after the 1993 and 1996/1997 harvests from the following peanut companies: Cargill Peanut Products, Dawson, GA, USA; Universal Blanchers, Dublin, TX, USA; Seabrook Enterprises, Inc, Sylvester, GA, USA; The Clint Williams Co, Madill, OK, USA; Hunt Wesson, Inc, Fullerton, CA, USA; Universal Blanchers, Blakely, GA, USA.

Grape spirit

Grape spirit (commercially produced in California) was purchased locally (Warehouse Package Store, Albany, GA, USA).

Solvents and reagents

All solvents and common reagents used were of reagent grade (Sigma Chemical Co, St Louis, MO, USA).

Isolation and purification of long-chain fatty acids

A 2 kg batch of rancid Florunner peanut skins (1993 harvest) was soaked in 11 l of hexane for 17 h at room temperature. The extract was filtered through glass wool to remove the skins, yielding *ca* 8 l of extract. This prefiltered extract was filtered through Whatman filter paper #1 (W & R Balston, Ltd, Maidstone, UK) to remove fine particles. The solvent was then removed in vacuum at 35 °C to yield 127.82 g (140 ml) of yellow oil, which gave 28 ml of yellowish white fine precipitate on cooling to room temperature. Before separating the precipitate, the mixture was kept in a refrigerator at 4 °C overnight. The recovery of oil from the first extraction was 6.39%. The hexane recovered from the first extraction was used for a second extraction. Addition of *ca* 1.5 l of fresh hexane was required to completely cover the skins. After extraction for 16 h the extract was processed as described above to yield 43.28 g (48 ml) of oil, which gave 11 ml of similar precipitate. Oil recovery from the second extraction was 2.16%. Total oil recovery was 8.56%. Purification of the precipitate was performed as follows. Liquid oil was decanted from the precipitate, which then was transferred to a porous glass filter with a minimum amount (40–60 ml) of cold (8–12 °C) hexane. The residue was vacuum filtered and washed with cold hexane (2 × 20 ml). After air drying overnight, an off-white powder was finally purified by distillation in low vacuum at 2×10^{-2} kg cm^{-2} using a heat gun as heat source. Vacuum distillation gave 13.2 g of white solid of low density (<1 g cm^{-3}) with a narrow mp range of 71.5–72.5 °C. It was soluble in $CHCl_3$, C_6H_6 and other common non-polar solvents, as well as in hot hexane and hot MeOH.

Oil extraction from peanut skins

A 100 g sample of peanut skins was extracted with hexane (3 × 700 ml) at room temperature. The combined extracts were filtered through fluted filter paper. The solvent was removed with a rotary evaporator at 40 °C to constant weight.

UV irradiation of peanut skins

A monolayer of peanut skins on a stainless steel tray was irradiated for 5.5 h with four 15 W UV lamps (360 nm max) positioned 12 cm above the skins.

Oxidation of peanut skin oil with $KMnO_4$

Oxidation was performed according to general recommendations for phase transfer-assisted oxidations with $KMnO_4$.[7] The oxidation was carried out at room temperature with an excess of an acetone solution of $KMnO_4$ at neutral pH. The reaction mass was continuously mixed with a magnetic stirrer. $KMnO_4$ solution was gradually added to 8% oil solution in acetone. After completion of the reaction the mixture was extracted twice with hexane. The viscous dark liquid that was not extractable with hexane was dissolved in acetone. The hexane extract was evaporated to dryness in vacuum and was directly used for further experiments. The acetone extract was subjected to further purification by column chromatography on silica gel; hexane/acetone (9:1 v/v) served as eluant. The hexane eluate was then evaporated in vacuum to dryness to give a colourless oil.

Oxidation of peanut skin oil with air

Oxidation was performed at room temperature for 36 h by passing air through 100 g of peanut skins placed in a 2 l (130 mm id × 160 mm) Pyrex filtering funnel with a fritted glass disc. The airflow rate was maintained at *ca* 5 l min^{-1}. After 36 h the oil from the skins was extracted with hexane as described above.

Standards of methyl esters of fatty acids

External and internal reference standards were authentic mixtures of free fatty acids (FFA) and FFA methyl esters (Aldrich, Milwaukee, WI, USA; Applied Science Laboratories, Inc, State College, PA,

USA; Alltech Associates Inc, Applied Science Lab, Deerfield, IL, USA).

Gas chromatographic (GC) determination of fatty acids

A Hewlett Packard 5890 series II gas chromatograph (GC) with a flame ionisation detector was used for analysis of the fatty acid methyl esters. The oven temperature was programmed for an initial temperature setting of 150 °C for 2 min, then increased at a rate of 5 °C min^{-1} until reaching a final temperature of 260 °C. The injector and detector temperatures were 260 and 270 °C respectively. The column was an AT-WAX (30 m × 0.25 mm id × 0.25 μm) column (Alltech Associates Inc). A Varian 4400 integrator (Varian Associates, Inc, Palo Ato, CA, USA) was used to record the retention time and peak area of fatty acids. The following carrier gases were used: H_2, 99.99+%, free from organic impurities, produced by a hydrogen generator (Whatman model 75-34); air, compressed, free from organic impurities; N_2, dried, containing <10 mg O_2 kg^{-1}.

Methyl esters of fatty acids

Methyl esters of fatty acids were prepared by treatment of 10–12 mg of oil in a 4 ml vial with an excess (1 ml) of 0.1 M aqueous (*m*-trifluoromethylphenyl)trimethylammonium hydroxide (Meth-Prep I, Alltech Associates Inc) at room temperature and vigorous shaking for 15–20 s. An aliquot of the mix was injected into the GC.

Transesterification of fatty acids

Transesterification of fatty acids to their methyl derivatives was done by treatment of a solution of 30–50 mg of oil in benzene with an excess (1 ml) of 0.1 M methanolic (*m*-trifluoromethylphenyl)trimethylammonium hydroxide (Meth-Prep II, Alltech Associates Inc) at room temperature. The reaction mixture was allowed to stand for 20–30 min before direct injection into the GC.

Making brandy

Peanut skins were defatted with hexane as described above and air dried. The skins were placed in an oven preheated to 150–165 °C for 20–25 min in the presence of air. The skins were added to commercial distilled grape spirit of 80 proof (40% v/v; placed in a glass food-grade bottle with a tight lid) at the ratio of 1.0–1.5 g to 100 ml respectively. The spirit was allowed to age at room temperature in the dark for 4–15 months. After that the brandy was filtered through fluted filter paper into a food-grade glass bottle with a tight lid.

Making liqueur

Peanut skins were treated in a similar way as for making brandy. Commercial corn or sugar syrup was mixed with food-grade ethyl alcohol to obtain 80–140 proof (40–70% v/v) of alcohol content and appropriate sweetness. The skins (1–2%) were added to the preheated (70–90 °C) alcohol/syrup mixture. The mixture was allowed to stand overnight at room temperature, then filtered through a cotton plug placed in a glass funnel. A thick, sweet, sticky transparent liquid of pinkish beige colour was obtained.

Making tea

Peanut skins were treated in a similar way as for making brandy. A 40 g sample skins was added to 1 l of boiling distilled water, boiled for 5 min and allowed to cool to room temperature. The cold extract was then filtered under vacuum through a filter paper to obtain a transparent, flavoured, bitter, highly concentrated liquid of brownish colour. The concentrate was mixed with local traditional sweet ice tea in ratios from 1:20 to 1:5 to obtain the final beverage.

Organoleptic analysis

Peanut brandy quality and flavour intensity were evaluated by 23 male panellists working in peanut research and the peanut industry. 'Napoleon' finest VSOP French brandy (Courriere & Co, Negociants, A16100, France) purchased locally (Warehouse Package Store, Albany, GA, USA) served as a reference standard. Evaluation was done at eight sessions by one to three panellists each time. Peanut liqueur flavour and tea flavour were evaluated by five people (from the same group of 23 panellists) at two sessions. No reference liqueur was used at the sessions.

Finishing decorative panels

Wood, metal, plastic or carton panels were finished using two techniques. Both methods employed dry defatted skins that were used as is or ground in a coffee mill followed by sieving through a 2–4 mm mesh, or defatted skins that were extracted with water. The latter gave twisted ('curly') flakes, which provided a three-dimensional look to the finish. The first technique consisted of spraying a panel with acrylic, latex or any other commercial paint designed for painting finished surfaces, pouring the skin flakes onto the freshly painted surface and evenly distributing them. A rubber roller was used to apply some pressure to the surface in order to provide better contact of the flakes with the paint. Excess skins were removed from the panel by turning it upside down and shaking. One or more coatings of the same paint were applied to the panel. The second technique consisted of mixing the skins with paint before application on a panel using a brush or a foam roller followed by drying.

RESULTS AND DISCUSSION

Potential oil recovery from peanut skins as well as some new uses of defatted skins may be considered as added value to the peanut industry. Fig 1 summarises the results of our research.

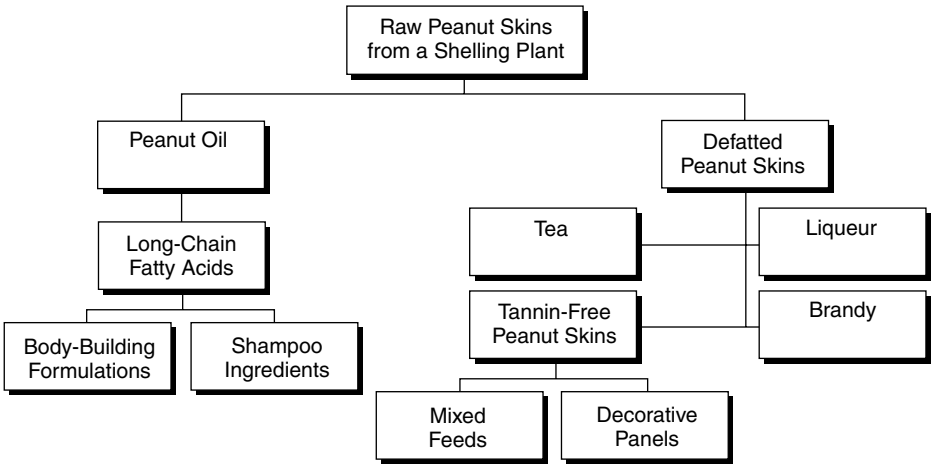

Figure 1. Utilisation of peanut skins.

Table 1. Oil content in peanut skins of different origin

#	Type and grade	Source[a] and sample label	Oil content[b] (%)	Comments
1	Florunner, medium	CP, 3BFS	8.37 ± 0.13	Old sample (1993). Skins smelt rancid. Oil gave precipitate of long-chain fatty acids spontaneously on cooling from 40 °C to room temp
2	Florunner, medium	CP, 3BFS	8.56 ± 0.18	Same as #1, but two extractions (first extraction overnight)
3	Florunner, medium	CP, 3BFS	7.55 9.13 8.98 8.64	Same as #1. Several samples from the same big lot (different sacks). Two consecutive extractions
4	Florunner, jumbo	SE, 2B5825	9.44 ± 0.21	1996 crop. No precipitate. Fluffy skins
5	Florunner, jumbo	UBGA, SPB	12.17 ± 0.12	1996 crop. No precipitate
6	Virginia, medium	SE	13.2 ± 0.14	1996 crop. No precipitate
7	Florunner, jumbo	CW	13.47 ± 0.18	1996 crop. No precipitate
8	Florunner, medium	UBGA, No 12	15.37 ± 0.44	1996 crop. No precipitate
9	Virginia	UB, No 5	18.52 ± 0.68	1996 crop. No precipitate
10	Spanish	UB, No 5	18.65 ± 0.71	1996 crop. No precipitate
11	Spanish	UB, SNB No 1A	18.73 ± 0.33	1996 crop. No precipitate
12	Florunner, medium	UB, No 5	20.35 ± 0.67	1996 crop. No precipitate
13	Florunner, medium	HW	17.00 ± 0.48	Old sample (1993). Two extractions. No precipitate
14	Spanish	UB, SNB No 1B	34.60 ± 0.62	1996 crop. No precipitate. Blanched at high temp
15	Spanish	UB, SNB No 1	33.80 ± 0.57	1996 Crop. No precipitate. Blanched at high temp.
16	Virginia	UB, No 5	18.34 ± 0.77	UV irradiated at 360 nm for 5.5 h. No precipitate
17	Virginia	UB, No 5	4.89 (hexane-sol) 7.44 (hexane-insol)	Treated with excess $KMnO_4$. No precipitate
18	Virginia	UB, No 5	18.43 ± 0.81	Treated with excess air for 36 h. No precipitate

[a] CP, Cargill Peanut Products, Dawson, GA, USA; UB, Universal Blanchers, Dublin, TX, USA; SE, Seabrook Enterprises, Inc, Sylvester, GA, USA; CW, The Clint Williams Co, Madill, OK, USA; HW, Hunt Wesson, Inc, Fullerton, CA, USA; UBGA, Universal Blanchers, Blakely, GA, USA.
[b] Values (except for ##3 and 17) are mean ± standard deviation ($n = 3$).

The research demonstrated that up to 35 g of oil could be extracted from 100 g of peanut skins using hexane. However, the oil content differed significantly among the analysed samples, ranging from *ca* 8 to *ca* 35% (Table 1, ##1–3 and ##14 and 15 respectively). Differences in oil content were related to differences in the blanching process. Skins from peanut seeds that were conventionally blanched at higher temperature (>107 °C; Table 1, ##14 and 15) showed significantly higher oil content. This type of blanching is actually a part of the peanut-roasting procedure. Samples 14 and 15 (Table 1)

Table 2. Methyl esters of fatty acids of total oil in peanut skins and kernels

#	Variety, grade, source[a] and sample label	16:0	16:1[b]	18:0	18:1[b]	18:2[b]	18:3[b]	20:0	20:1[b]	22:0	24:0
1	Florunner, UB, No 5	11.32	0.57	2.24	38.46	33.51	0.57	2.58	2.31	6.30	2.14
2	Florunner, medium, HW	11.24	0.70	2.38	42.32	32.35	0.21	2.49	1.57	4.45	2.29
2a	Florunner, medium, HW, kernels	11.06	0.52	2.36	46.73	28.36	0.25	2.36	1.36	4.37	2.63
3	Florunner, jumbo, UBGA, SPB	11.18	0.51	2.50	42.33	31.42	0.37	1.58	1.90	5.95	2.26
4	Florunner, jumbo, SE, 2B5825	10.96	0.45	2.39	41.60	32.71	0.78	1.57	2.07	5.36	2.11
5	Florunner, jumbo, CW	11.52	0.59	2.22	39.60	35.65	0.48	1.55	1.69	4.46	2.24
6	Florunner, medium (rancid odour), CP, 3BFS	17.33	0.17	3.76	51.56	12.70	1.31	1.60	0.42	8.53	3.13
7	Florunner, medium, UB, No 5	9.02	0.62	2.10	46.45	30.03	0.18	1.25	0.96	6.57	2.82
8	Spanish, UB, SNB No 1	12.60	0.60	3.15	36.24	37.54	0.46	1.99	1.53	4.13	1.76
9	Spanish, UB, No 5	10.91	0.59	2.84	43.44	30.83	0.59	2.42	2.10	4.53	1.75
10	Spanish, UB, SNB No 1, kernels	11.30	0.64	3.64	42.17	34.91	0.24	1.68	1.01	3.11	1.30
11	Virginia, UB, SNB No 1	10.24	0.51	2.64	40.51	28.56	0.34	2.46	1.83	8.81	4.10
12	Virginia, medium, SE	8.45	0.61	2.99	50.03	27.71	0.14	2.03	0.95	5.65	1.44
13	Virginia, UB, No 5, kernels	10.25	0.54	2.62	43.91	29.42	0.74	1.65	2.96	5.95	1.96
14	Virginia, UB, No 5, UV irradiated	11.14	0.43	2.89	43.78	31.32	0.29	2.17	1.63	4.56	1.79
15	Virginia, UB, No 5, $KMnO_4$ treated, hexane fraction	13.02	0.46	3.48	52.86	18.07	0.60	2.48	2.19	5.09	1.75
16	Virginia, UB, No 5, $KMnO_4$ treated, acetone fraction	15.83	0.59	3.90	52.19	17.97	0.51	3.47	1.81	1.13	2.60
17	Florunner, medium, 3-year-old skin oil, kept at room temp exposed to light	12.04	0.15	2.36	46.33	25.07	0.00	2.55	2.29	5.51	3.70

[a] See Table 1 for source abbreviations used.
[b] *Cis* fatty acids: palmitoleic ($16:1^{\Delta 9}$), oleic ($18:1^{\Delta 9}$), linoleic ($18:2^{\Delta 9,12}$), linolenic ($18:3^{\Delta 9,12,15}$) and eicosenoic ($20:1^{\Delta 9}$) respectively.

Table 3. Methyl esters of free fatty acids in oil from peanut skins and kernels

#	Variety, grade, source[a] and sample label	16:0	16:1[b]	18:0	18:1[b]	18:2[b]	18:3[b]	20:0	20:1[b]	22:0	24:0
1	Florunner, UB, No 5	11.49	0.20	2.31	39.11	33.45	1.17	1.43	1.29	7.03	2.52
2	Florunner, medium, HW	12.37	0.12	2.72	53.82	15.31	1.66	7.24	1.48	3.89	1.39
3	Florunner, jumbo, UBGA, SPB	11.02	0.26	2.41	40.20	28.83	1.32	1.54	3.01	9.37	2.04
4	Florunner, jumbo, SE, 2B5825	10.43	0.18	2.28	38.78	27.84	2.02	1.80	1.72	12.91	2.04
5	Florunner, jumbo, CW	11.62	0.26	2.26	39.53	34.52	1.37	0.94	1.53	5.70	2.27
6	Florunner, medium (rancid odour), CP, 3BFS	19.40	0.00	4.23	54.22	7.12	0.76	2.79	2.27	4.93	4.48
7	Florunner, medium, UB, No 5	9.46	0.20	2.11	46.54	28.37	2.93	2.84	1.45	4.10	2.00
8	Spanish, UB, SNB No 1	12.08	0.21	2.91	33.61	33.61	1.51	1.36	2.78	10.27	1.66
9	Spanish, UB, No 5	11.14	0.17	2.61	40.41	26.70	1.96	1.75	1.96	11.65	1.65
10	Spanish, UB, SNB No 1, kernels	11.45	0.22	3.53	41.13	32.19	2.61	2.28	1.30	3.92	1.37
11	Virginia, UB, SNB No 1	10.79	0.24	2.82	41.90	28.54	1.57	1.70	3.15	7.70	1.59
12	Virginia, medium, SE	8.86	0.25	2.83	49.13	25.97	3.22	2.21	3.04	2.87	1.62
13	Virginia, UB, No 5, kernels	10.75	0.25	2.71	43.98	28.07	1.24	2.03	2.85	6.43	1.69
14	Virginia, UB, No 5, UV irradiated	11.42	0.27	2.90	43.46	29.50	1.96	1.73	1.65	5.31	1.80
15	Virginia, UB, No 5, $KMnO_4$ treated, hexane fraction	12.63	0.28	3.54	44.62	6.69	1.48	2.94	4.48	14.04	9.30
16	Virginia, UB, No 5, $KMnO_4$ treated, acetone fraction	15.48	0.47	3.91	50.58	12.18	2.88	2.39	2.34	6.81	2.96

[a] See Table 1 for source abbreviations used.
[b] *Cis* fatty acids: palmitoleic ($16:1^{\Delta 9}$), oleic ($18:1^{\Delta 9}$), linolenic ($18:2^{\Delta 9,12}$), linolenic ($18:3^{\Delta 9,12,15}$) and eicosenoic ($20:1^{\Delta 9}$) respectively.

showed high levels of oil content, similar to the oil obtained by cold pressing from kernels of the same lot (Table 2, ##2 and 2a and Tables 2 and 3, ##8 and 10). The oil from the skins had a slightly darker colour than pressed oil. When blanching took place at lower temperature (<107 °C; all samples in Table 1 except ##14 and 15) and was performed only for the purpose of removing the skins, the oil content in the skins was in the range 9.44–20.35%. The apparent explanation for this difference is that, at higher temperatures, peanut kernels release more oil, which is absorbed by the skins. No significant difference in skin oil content was demonstrated among popular market types of the 1996 harvest (Table 1, ##4–12).

The most interesting results were obtained from the analysis of an old peanut skin stock that was available from a local source (Table 1, ##1–3). By the time the samples from this lot were analysed, the skins were about 18 months old and had some rancid odour. After removal of the solvent in vacuum and cooling to room temperature, the oil gave a fine precipitate of yellowish white colour. In contrast, no precipitates were observed in the oil from fresh samples of skins

Table 4. Methyl esters of saturated fatty acids of precipitate isolated from rancid skins

	Fatty acid											
	16:0	18:0	20:0	21:0	22:0	23:0	24:0	25:0	26:0	27:0	28:0	30:0
Concentration (%)	0.05	0.55	6.56	0.32	52.28	1.08	30.51	0.65	4.68	0.29	2.21	0.82

under the same conditions. One sample of the skins of 1993 (Table 1, #13) was kept in a refrigerator at the NPRL before oil extraction and did not produce any precipitate as well.

After isolation and purification of the precipitate, GC analysis showed that it represented a mixture of long-chain saturated fatty acids with two major components, behenic (22:0) and lignoceric (24:0) acids (about 83% of the total, Table 4). Both these fatty acids are used in body-building formulations (http://www.bodybuilding.com/store/univ/sterol.html) and as ingredients in shampoos (http://www.hairsite.com/ingredients/ingcond.htm). The next most abundant components were arachidic (20:0) and cerotic (26:0) acids, with a combined content of more than 11%. It should be noted that traces of saturated fatty acids with odd carbon atom numbers were also detected (Table 4). Analysis of the fatty acid composition of the homogenised rancid oil showed a reduced concentration of unsaturated fatty acids such as palmitoleic ($16{:}1^{\Delta 9}$), linoleic ($18{:}2^{\Delta 9,12}$) and eicosenoic ($20{:}1^{\Delta 9}$) acids both in the form of triglycerides (Table 2, #6) and in the form of FFA (Table 3, #6). The concentration of unsaturated $16{:}1^{\Delta 9}$, $18{:}2^{\Delta 9,12}$ and $18{:}3^{\Delta 9,12,15}$ (linolenic) fatty acids in the form of FFA was significantly lower than that in the form of triglycerides (Table 3, #6). At the same time the concentration of saturated fatty acids such as 16:0, 18:0 and 22:0 was higher compared with reference oils (Tables 2 and 3, #6). An increased concentration of oxidised oils with higher polarity in such an oil could cause the precipitation of chemically stable fatty acids such as 22:0 or 24:0. Attempts to artificially cause similar precipitation from a fresh peanut skin oil included its gradual oxidation with $KMnO_4$ (Table 1, #17 and Tables 2 and 3, ##15 and 16 show the results of oxidation with excess $KMnO_4$) as well as oxidation of the skins before oil extraction either with UV irradiation (Table 1, #16 and Tables 2 and 3, #14) or with constant air flow through the skins (Table 1, #18). These attempts were not successful. Understandably, $KMnO_4$ did oxidise the unsaturated fatty acids (Tables 2 and 3, ##15 and 16), but no precipitation was observed. In contrast, neither UV irradiation nor air oxidation caused any significant changes in oil composition (Tables 2 and 3, #14). Oil seems to be naturally protected from oxidation to some degree, but oxidation does take place over time.

The oil composition of the analysed samples showed some variability (Tables 2 and 3), which is typical for different peanut cultivars from different geographical locations.[4] Some difference in concentrations between FFA and total oil fatty acids was also in agreement with previous findings.[8] Comparison of the oil composition obtained from the skins and kernels of the same peanut lot (Table 2, ##2, 2a, 8 and 10 and Table 3, ##8 and 10) showed significant differences in $18{:}1^{\Delta 9}$ (oleic) and $18{:}2^{\Delta 9,12}$ fatty acid concentration. Oil from the kernels had a higher $18{:}1^{\Delta 9}$ fatty acid concentration than oil from the skins. At the same time, $18{:}2^{\Delta 9,12}$ fatty acid was found at lower concentration in the kernels. Oil from the kernels showed a higher O/L ratio than that from the skins (1.65 for the kernel oil vs 1.31 for the skin oil, ##2 and 2a, Table 2; 1.21 vs 0.97, ##8 and 10, Table 2; 1.28 vs 1.00, Table 3), which suggests its better stability. Organoleptic properties of oils from both the skins and the kernels were identical. The flavour was indistinguishable from that of commercial peanut oil.

Defatted peanut skins were found to be useful for making both alcoholic and non-alcoholic beverages such as brandy, liqueur and tea. Tannins, catechol-type compounds and other extractive compounds found in peanut skins[1,9] could serve as a medium for aging grape spirit to obtain a brandy-like beverage. The method consists of aging distilled grape spirit with defatted, thermally treated peanut skins for several months. The method permits the aging in containers other than expensive oak barrels, traditionally used for this purpose. The aging time is also dramatically reduced. Ripe peanut 'brandy' can be blended with other types of brandy, if required, and bottled at 80 proof. Appropriate as an after-dinner drink, it can also be used in mixed drinks as well as for cooking. The method allows for production of a new product with pleasant organoleptic properties. Sensory evaluation of brandy flavour relied on the use of human subjects. The subjective panellists' judgement can be summarised as follows: 'rich amber colour; intense, highly extracted and bold, but in balance; flavours grow throughout the taste experience, ending with a pleasant aftertaste'.

The commercial potential derives from the use of cheap treated peanut skins instead of expensive oak barrels for aging the spirit, which dramatically reduces the aging time and makes the production of brandy significantly cheaper.

The time required for making a strongly flavoured alcoholic liqueur of peanut skins with corn or sugar syrup and ethyl alcohol is much shorter than that described for brandy (see 'Experimental'). The method consists of extracting treated peanut skins with 160–180 proof ethyl alcohol and mixing the extract with corn or sugar syrup to an appropriate sweetness. The peanut 'liqueur' can be bottled at

40–140 proof. Other flavouring extracts can also be used together with the peanut skin extract to change or improve the organoleptic properties of the liqueur. The panellists judged the beverage as 'nicely sticky-sweet, highly flavoured, rich with a satisfying aftertaste'. It had light a pinkish beige to pinkish brown colour.

The non-alcoholic beverage made from the skins had a taste resembling that of tea. The peanut 'tea', when mixed with black tea, had a pleasant bittersweet chocolate background with sizable but not tough tannins and subtle notes of peanut butter. After extraction of water-soluble compounds, particularly tannins, the skins are assumed to be enriched with proteins and could be used in mixed feeds for cattle at higher ratios than those used with conventional peanut skins. However, experiments remain to be performed to confirm this statement.

As an alternative, defatted peanut skins were successfully used for finishing decorative panels to give a new, beautiful appearance. The technique of mixing the skin flakes with paint rather than spraying paint on the skins (see 'Experimental') provided a more solid appearance of the panels as well as a functionally sound decorative material. Its use for making textured ceiling tiles seems to be the most appropriate.

CONCLUSIONS

The research demonstrated potential uses of peanut skins that included extraction of high-quality oil, making beverages and finishing decorative panels. Easy and permanent raw material supplies at low cost, affordable processing and the absence of natural or artificial toxic constituents make products from peanuts skins very attractive.

ACKNOWLEDGEMENTS

The authors thank P Blankenship of the National Peanut Research Laboratory, ARS, USDA (Dawson, GA, USA) for the samples of peanut skins, and the officials of the companies listed in 'Experimental' for providing the samples of peanuts and peanut skins.

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