MAXIMIZING FUNCTIONAL COMPOUNDS IN FOOD INGREDIENTS FROM PEANUT KERNELS AND SKINS

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Non Technical Summary
Compounds beneficial to health, such as phenolics and antioxidant compounds have been identified in peanuts and peanut skins. These compounds reduce the risk of cardiovascular disease and cancer, among other health benefits. The concentration of functional compounds in peanut kernels can be enhanced by applying stresses to peanut kernels through ultraviolet light and ultrasound or combination of both treatments. The sensory properties of this ingredient need to be defined and its acceptability to consumers need to be maximized before peanut processors can use them in peanut products. Peanut skins are a by-product of the peanut processing industry with very low economic value. The increasing consciousness of consumers with regard to food additive safety necessitates the identification of alternative natural sources of food antioxidants to improve the quality of food. Extracts of peanut skins have tremendous potential benefit to the food industry as an alternative source of antioxidants in different food systems. This research aims to produce functional peanuts and peanut by-products containing increased levels of bioactive compounds and antioxidant capacities. Development of functional peanuts, and use by food manufacturers would increase the phytochemicals' availability to consumers, maximize health benefits and increase peanut profitability. These products will create market opportunities for peanuts and increase the value of agricultural by-products such as peanut skins.

Animal Health Component

25%

Research Effort Categories

Basic

25%

Applied

25%

Developmental

50%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
501	1830	1010	10%
501	1830	2000	40%
502	1830	2000	10%
502	1830	3090	40%

Knowledge Area
501 - New and Improved Food Processing Technologies; 502 - New and Improved Food Products;

Subject Of Investigation
1830 - Peanut;

Field Of Science
1010 - Nutrition and metabolism; 2000 - Chemistry; 3090 - Sensory science (human senses);

Keywords
functional compound
peanut kernels
peanut skins
phenolic compounds
antioxidants
functional peanut
antioxidant capacity
resveratrol
piceid
size reduction
uv light
ultrasound

Goals / Objectives
Our goal is to maximize functional components in peanut kernels and skins, as food ingredients and food products, for disease prevention, health, and maintenance of food quality. The objectives are to maximize resveratrol, piceid, and phenolic compounds and antioxidant capacity of peanut kernels and skins by postharvest stress treatments and heat processing for the design and development of functional peanuts for use as an ingredient and natural antioxidants in various peanut and food products.

Project Methods
We propose to maximize functional compounds and antioxidant capacity in peanut kernels by application of postharvest stress treatments such as UV light and ultrasound processing. Resveratrol, piceid and phenolic compounds and antioxidant capacities in peanut kernels by application of UV light of varying irradiation distances and times that will result in functional peanut kernels with acceptable sensory properties will be optimized. The use of ultrasound processing treatment to produce functional peanuts will be also be optimized by varying the power densities and exposure times. The additive or synergistic effect of combining UV and ultrasound treatment in enhancing the functional compounds in peanut kernels will be studied. Phenolics and antioxidant capacity of peanut skins from three peanut cultivars will be maximized by heat treatment using different temperatures and times. The established process developed will be applied to commercial peanuts skins as source of antioxidant ingredient. The antioxidant effectiveness of the peanut skin extract as a functional ingredient in selected food systems (edible oils, emulsion and muscle foods) will be determined and compared against commercial food antioxidants. Chemical analyses to determine the total phenolics and antioxidant capacities of the kernels and skins will be applied. These are the Folin-Ciocalteu method, oxygen radical absorbance capacity and the ABTS radical scavenging capacity. A profile of phenolic compounds, resveratrol and piceids, and their concentrations will be determined through high performance liquid chromatography. Sensory analyses (consumer and descriptive) will be conducted to determine acceptability of functional peanuts and sensory characteristics of products developed with the functional peanut ingredients.

Progress 07/01/09 to 06/30/10

Outputs
OUTPUTS: A. The effects of 27 varying doses of UV and ultrasound (US), and incubation times at 25 C on total phenolics and antioxidant capacities, and sensory overall acceptance of sliced peanut kernels were investigated. Parameters for UV were distance from UV light (20, 40, 60 cm) and exposure time (10, 20, 30 min); and for US, were power density (25, 50, 75 mW/cc) and

exposure time (2, 5, 8 min); both followed by incubation time at 25 C of 24, 36 and 48 h. Total phenolics was analyzed using Folin Ciocalteau method, antioxidant capacities by two methods, trolox equivalent antioxidant capacity (TEAC) and oxygen radical absorbance capacity (ORAC) using hydrophilic and lipophilic assays, and overall acceptance by 50 consumers using 9-point hedonic rating scale (1=dislike extremely; 5= neither like nor dislike; 9 like exteremely) in a consumer acceptance test. Optimum UV or US processes were determined using response surface methodology. B. Peanuts are known to synthesize resveratrol, a stilbene phytoalexin, associated with cancer chemopreventive activity and cardioprotection. A modified HPLC method to determine trans-resveratrol and trans-piceid concentration in a single analysis, was developed and validated for recoveries, precision, linearity, and limits of detection and quantification. The effect of combined treatments, fixed ultrasound dose (40 mW/cc for 4 min) followed by varying UV doses (3 distances from UV light of 20, 40, 60 cm; 3 exposure times of 15, 35, 55 min) and incubation at 25 C for 44 h on trans-resveratrol and trans-piceid concentrations in peanuts was determined. PARTICIPANTS: Anna V. A. Resurreccion, Professor, was the principal investigator on this project. TARGET AUDIENCES: The peanut processing industries will benefit by the knowledge of processing and the value-added product technologies; and consumers who will obtain the health benefits from bioactive-enhanced peanut products developed in this project. PROJECT MODIFICATIONS: Not relevant to this project.

Impacts

A. UV and ultrasound increased total phenolics and antioxidants of most treated peanuts whereas overall acceptance decreased in all treatments compared to untreated controls. Total phenolics of UV and US treated peanuts increased to 1.38-1.82 and 1.22-1.89 mg GAE/g, respectively, compared to 0.84 mg GAE/g in untreated controls. Total phenolics of US and UV treated peanuts were equal at longer incubation times of 36 and 48h, but not at lowest incubation time of 24h where UV had higher than US treated samples. Total phenolics of UV and US treated peanuts were within those of blueberry wines (0.60-1.86 mg GAE/g) and within the lower limits of fresh blueberry purees (1.81-4.58 mg GAE/g) and red wines (1.31-2.39 mg GAE/mL). TEAC of UV and WE treated peanuts increased to 2.84-3.37 and 2.21-3.17 microM TE/g, respectively, from 0.61 microM TE/g in untreated controls. At all incubation times, UV had higher TEAC than US treated peanuts were in the lower limits of 16 types of red wines (3.06-11.15 microM TE/mL). ORAC total antioxidant capacity (TAC), the sum of hydrophilic and lipophilic antioxidants of UV and US treated peanuts increased to 32.65-100.20 and 50.00-96.92 microM TE/g from 26.81 microM TE/g in controls. Ultrasound was more effective than UV in increasing ORAC. UV treated peanuts had higher overall acceptance (mean hedonic rating=5.7, range = 5.0-6.3) compared to ultrasound treated peanuts (mean = 5.1; range 4.2-6.0). Both UV and US treated samples had lower overall acceptance than controls with mean hedonic rating of 7.4. Optimum ultrasound process parameters at 36h incubation time will result in products with equal to or more than 68 microM TE/g ORAC-TAC, 1.51 mg GAE/g total phenolics, 2.76 microM TE/g TEAC, and 5 or either like nor dislike hedonic rating. B. A modified HPLC method developed and validated to simultaneously determine trans-resveratrol and trans-piceid concentrations, exhibited recoveries (99.2, 108.0, 112.1% for trans-resveratrol; and 124.22, 112.8, and 113.3% for trans-piceid); precision (coefficient of variations of 1.89, 1.52, and 2.17% for trans-resveratrol, piceid and phenolphthalein, respectively); linearity (correlation coefficient of 0.9997, 0.9994 and 0.9999 for trans-resveratrol, trans-piceid, and phenolphthalein, respectively); limits of detection (0.0125, 0.0125 and 0.050 for trans-resveratrol, trans-piceid, and phenolphthalein, respectively); and limits of quantification (0.05, 0.05, and 0.125 for trans-resveratrol, piceid and phenolphthalein, respectively) which were all consistent or better than methods previously reported in the literature. All the nine US-UV treatments significantly increased trans-reservation contents from 0.03 pap, in untreated peanut controls, to 2.10 - 4.73 pap; and trans-pieced from 0.07 pap to 0.23-0.38 pap. Increases in trans-reservation were not influenced by UV distance and time. US or UV, individually, increased trans-reservation to 4.29 ppm and 2.36 ppm, respectively. The US-UV treatment combinations used did not exhibit synergistic effect compared to US treatments alone.

Publications

- Francisco, M.L.dL. and Resurreccion, A.V.A.(2009). Development of a reversed-phased high performance liquid chromatography (RP-HPLC) procedure for the simultaneous determination of phenolic compounds in peanut skin extracts. Food Chemistry, 117(2), 356-363.
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- Sales, J.M. and Resurreccion, A.V.A.(2009). Maximising resveratrol and piceid contents in UV and ultrasound treated peanuts.Food Chemistry, 117(3), 674-680.
- Sales, J.M. and Resurreccion, A.V.A.(2010). Maximizing phenolics, antioxidants, and sensory acceptance of UV and ultrasound treated peanuts. LWT-Food Science and Technology. DOI:10.1016/j.lwt.2010.02.009(in press)
- Francisco, M.L.dL., and Resurreccion, A.V.A.(2009). Antioxidant capacity and phenolic compounds in peanut skin extracts. (abstract#159-17). Institute of Food Technologists Annual Meeting, Anaheim, CA. June, 2009.
- Resurreccion, A. V., Francisco, M.L. d., and Sales, J. M. (2009). Maximizing functional compounds in food ingredients from peanut kernels and skins. (abstract#126-28)Institute of Food Technologists Annual Meeting, Anaheim, CA. June, 2009.
- Potrebko, I. and Resurreccion, A.V.A. (2009). The effect of UV doses in combined UV-ultrasound treatments on resveratrol and piceid content in sliced peanut kernels. (abstract#126-05)Institute of Food Technologists Annual Meeting, Anaheim, CA. June, 2009.
- Sales, J. M. and Resurreccion, A.V.A. (2009). Optimizing UV and ultrasound processes for increased phenolics and antioxidant capacities in peanut kernels.(abstract#028-18)Institute of Food Technologists Annual Meeting, Anaheim, CA. June, 2009.

Progress 07/01/08 to 06/30/09

Outputs

OUTPUTS: A. Peanuts skins contain potent antioxidants. Heat is known to increase the antioxidant capacity of peanut skins. Antioxidant capacity of peanut skins was maximized using heat processes for development of functional peanuts, for ingredient and natural antioxidant applications in various peanut and food products. The effect of heat processing on antioxidant capacity (AOC) from Runner, Virginia and Spanish peanut types was determined. Raw skins from the 3 peanut types were heated at 5, 15 and 25 min at 5 temperatures between 90 -180 C. Heated skins were extracted with 70% ethanol and AOCs were measured using Trolox equivalent antioxidant (TEAC) and Peroxyl-radical trapping capacity (PRTC) assay. B. As peanut skins were identified as one of the most important sources of antioxidants it is imperative to accurately determine and quantify phenolic compounds in peanut skins. A reversed-phase high performance liquid chromatography (RP-HPLC) method for identification and quantification of 15 compounds, including phenolic acids, flavonoids and stilbenes from peanut skin extracts, using beta-resorcylic acid as internal standard (IS), was developed. The HPLC system consisted of a C18 column fitted with diode array allowing simultaneous detection of phenolic acids, flavonoids and stilbenes, with mobile phase consisting of 0.1% formic acid in water and 0.1% formic acid in 100% acetonitrile. Mobile phase gradient solvent composition and gradient steepness were varied. The method was

validated for accuracy, precision, linearity, limit of detection and limit of quantification. The method was used to quantify phenolic compounds in peanut skin extracts from Runner, Virginia and Spanish peanuts. C. The effect of abiotic stress, UV, on maximizing functionality of sliced peanuts kernels while maintaining consumer acceptance was determined. The optimum UV processes for stilbenes, resveratrol and piceid, concentrations in peanuts were obtained by UV treatments of 10, 20 and 30 min of irradiation time (IT) and a distance (ID) of 20, 40, 60 cm from the source and incubated at 24, 36 and 48 h, using response surface methodology (RSM). Concentrations of resveratrol and piceid were determined using reversed phase HPLC method. Consumer acceptance ratings were obtained. Prediction models for the resveratrol, piceid, and overall acceptance of treated peanuts were developed to generate combinations of UV parameters for optimum processes. These are characterized by 2.6 ppm of resveratrol in red wines and overall acceptance ratings as close to or higher than 6. D. The effects of abiotic stress, ultrasound (US), on maximizing functionality of sliced peanuts kernels while maintaining consumer acceptance were determined. The optimum US processes for stilbenes, resveratrol and piceid, concentration in peanuts were obtained by US treatments of power density (PD) of 25, 50 and 75 mW/cc with exposure time (PT) of 2, 5 and 8 min and incubated at 24, 36 and 48 h, using response surface methodology (RSM). The optimum US processes are characterized by concentration of resveratrol more than 2.6 ppm in red wines and overall acceptance ratings as close to or higher than 6. PARTICIPANTS: Dr. Anna V.A. Resurreccion, professor, served as principal investigator on the project Ms. Inna Potrebko, research Technician III was responsible for method development, conduct analysis, data interpretation. Mr. Lary Hitchcock a state employed research professional performed development of methods, ordering equipment and chemicals troubleshooting, disposal of toxic waste, assisted with publication of papers. Mrs. Paula Scott, employed on non-federal funds, laboratory helper, recruited panelists, maintained consumer databases, assisted in sensory tests. Sue Ellen Mc Cullough, state employed laboratory technician, recruited panelists, maintained consumer databases, assisted in sensory tests. McCleskey Mills and American Peanut Blanchers, Industry partners, donated raw peanuts for research. University of Georgia Professional development: Lotis Francisco, PhD student, 40%, conducted day-to-day research on peanut skins. Joyce Sales, PhD student, 35%, conducted day-to-day research on peanut kernels TARGET AUDIENCES: Nothing significant to report during this reporting period. PROJECT MODIFICATIONS: There were considerable delays in the student's experiments; the students are on 35-40% assistantships. These delays also had impact on the rate of expenditure. There were no changes in approved objectives, methods and protocols. However we applied for a no-cost extension project to complete project objectives.

Impacts

A. Among three types of peanuts, Runners had significantly ($P< 0.05$) higher TEAC and PRTC values than Virginia and Spanish types. Maximum TEAC (2.56 mM TEAC/g) and PRTC values (31 mM Trolox/g) were obtained with Runners heated at 135 C for 5 min. Regression analysis showed that TEAC values could be predicted by temperature and time for Runner, Virginia and Spanish, but PRTC values could be predicted for Runner and Virginia types only. Generally, mild heat treatments (<135 C, 5 to 15 min) further enhances antioxidant capacity of peanut skins. Results indicated that skins from the three peanut types, raw or heat treated based on their AOCs, are exceptional sources of functional compounds. B. The present method developed simultaneously quantified compounds, classified under flavonoids, phenolic acids and stilbenes. The final HPLC method consisted of three gradient elution segments, which allowed separation of more polar compounds, the benzoic acid derivatives; the flavanols; and lastly, eluted less polar compounds. Phenolic compounds were eluted within 95 min, with good resolution. Recoveries of 15 compounds in peanut skin extracts ranged from 58 to 119 %. Precision ranged from 0.7 to 2.1 %. Linearity expressed as correlation coefficients, r, of 15 compounds were > 0.999. Limits of detection ranged from 0.1 to 0.9 ppm. In three peanut skin types, the phenolic acids protocatechuic and p-coumaric acids were identified and quantified; caffeic acid was found only in Spanish skins. Among the flavonoids, catechin, epicatechin epigallocatechin, procyanidin B2 and

quercetin were also quantified. Resveratrol but no piceid was detected in all peanut types. C. In peanuts, UV increased resveratrol and piceid but decreased overall acceptance of sliced treated peanuts compared to controls. Control untreated peanuts had 0.02 and 0.03 micrograms/g resveratrol and piceid, respectively, and an overall acceptance of 7.4 or 'like moderately'. Resveratrol in treated peanuts ranged from 0.5 to 3.5 ppm. Optimum UV processes include: all process combinations within the area of a triangle bound by the points, IDs of 47, 41 and 33 cm at exposure times of 30, 26 and 30 min, respectively, all incubated for 36h. These will provide up to 2.06 micrograms/g resveratrol, 0.47 microgram/g piceid, and an overall acceptance of ≥5.5 or 'neither like nor dislike'. D. Ultrasound treatment increased resveratrol and piceid but decreased overall acceptance of treated peanuts. Resveratrol in treated peanuts ranged from from 0.3 to 6.4 ppm, and piceid from 0.2 to 6.4 ppm. Optimum ultrasound processes include all the process combinations within a pentagon bounded by the points, PD of 75, 75, 72, 67 and 66 mW/cc at exposure times of 5.2, 8, 8, 7.1 and 5.5 min ,respectively, all incubated for 48h. These will provide up to 4.4 micrograms/g resveratrol, and an overall acceptance of ≥ 5. Peanut kernels treated with the abiotic stress, ultrasound, produced higher resveratrol and piceid but slightly lower overall acceptance, compared to UV. The optimum US process will produce 2.6- 4.4 ppm resveratrol, an amount greater than 2-2.06 ppm achieved by the optimum UV process.

Publications

- Francisco, M.L.dL. and A.V.A Resurreccion. 2008. Functional components in peanuts. Critical Reviews in Food Science and Nutrition 48(8):715-746.
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- Sales, J.M. and Resurreccion, A.V.A. 2008. Resveratrol and piceid contents of peanuts treated with combined ultrasound and UV irradiation. (Abstract 177-77) Ann. Mtg. Inst. Food Technologists, New Orleans, LA, June 28- July 1.
- Francisco MLdL and Resurreccion A.V.A. 2008. Total antioxidant capacity of peanut skins. (Abstract 177-66) Ann. Mtg. Inst. Food Technologists, New Orleans, LA, June 28- July 1.
- Resurreccion A.V.A. and Francisco MLdL 2008. Total phenolics and antioxidant capacity of peanut skins and their potential in antioxidant-rich Abstract T-1804 The 14th World Congress of Food Science and Technology, Shanghai, China, October 20.
- Resurreccion A.V.A. 2008. Functional Components in Peanuts. Abstract S07-4 The 14th World Congress of Food Science and Technology, Shanghai, China, October 22.

Progress 07/01/07 to 06/30/08

Outputs

OUTPUTS: A. The effect of heat treatment on antioxidant capacity of peanut skin extracts was investigated. Raw peanuts (Georgia Green runner (GA), Virginia (VA) and Spanish (SP) peanuts) were heated at various time (5 to 25 min) and temperature (90 to 180 C) conditions, blanched and skins were collected. Peanut skin extracts were analyzed for oxygen radical absorbance capacity (ORAC) including hydrophilic (H-ORAC), lipophilic (L-ORAC) and total antioxidant capacity (TAC). ORAC values are expressed as umol Trolox equivalents (TE)/g of dry weight. A profiling method that separates, detects and quantifies all the phenolic compounds in the peanut skin extract is currently being conducted. B. The effects of the combined ultrasound (US) and UV treatments on the concentrations of resveratrol, piceid, and total stilbenes (resveratrol + piceid) of chopped peanuts 2-5 mm thick were investigated. Samples were exposed to US for 1, 5, and 7 min (PT) at a fixed power density of 25 mW/cc followed by UV for 10, 25, and 40 min (IT) at a fixed distance from UV lamp of 40 cm from UV lamp, and incubated at 25 C for 24h. C. The

effects of varying doses of UV on ORAC of sliced peanuts were studied. Samples were exposed to UV for 10, 20, and 30 min (IT) at distances from UV lamp (ID) of 20, 40, and 60 cm, and incubated at 25C (IC) for 24, 36, and 48h. D. The effects of varying doses of ultrasound on ORAC values of chopped (2-5 mm), sliced (7 mm) and whole (14 mm) peanuts were investigated. The samples were exposed to ultrasound power densities (PD) of 25, 50 and 75 mW/cc for 2, 5 and 8 min (PT) and incubated at 25C for 24, 36 and 48h. E. The effect of order of the steps, UV and ultrasound (US), in a combined US-UV process to maximize resveratrol and piceid in sliced peanut kernels was determined. F. An HPLC RP method for resveratrol and piceid analysis was developed and validated. Recoveries of peanut extracts were determined for 4 concentrations: 0.3, 1, 5 and 10 ppm (n=3). Precision was expressed as coefficient of variations (CV). Limit of detection (LOD) and limit of quantification (LOQ) for piceid, resveratrol were determined. G. The effect of varying UV exposure time (15, 35, 55 min) and UV distance (20, 40, 60 cm) on resveratrol and piceid concentration of US treated peanuts (power density of 40 mW/cc for 4 min) was determined. Consumer acceptance and descriptive analysis tests were conducted on resveratrol enhanced peanuts and peanut skin extracts. Sensory results are being analyzed and interpreted. PARTICIPANTS: Dr. Anna V.A. Resurreccion, professor, served as principal investigator on the project Ms. Janice Nellas was hired as a technician and participated in day-to day performance of project tasks such as providing input on HPLC methodology, troubleshooting, chemical analysis, methodology, analysis of data, interpretation of HPLC results. Ms. Inna Potrebko was hired as a research technician and was responsible for method development, analysis, data interpretation. Mr. Lary HItchcock a state employed research professional performed development of methods, ordering equipment and chemicals, troubleshooting and disposal of toxic waste. Mrs. Paula Scott, employed on non-federal funds, laboratory helper, recruited panelists, maintained consumer databases, assisted in sensory tests. Mrs. Sue Ellen McCullough, state employed laboratory technician, recruited panelists, maintained consumer databases, assisted in sensory tests. McCleskey Mills and Bird Song Peanuts Inc., Industry partners, donated raw peanuts for research. University of Georgia Professional development: Lotis Francisco, PhD student, 40% time, conducted day-to-day research on peanut skins. Joyce Sales, PhD student, 35% time, conducted day-to-day research on peanut kernels TARGET AUDIENCES: Peanut processors, food manufacturers, consumers, stakeholders, public and private industry associations/collaborators, food scientists PROJECT MODIFICATIONS: There was considerable delay in implementation of the project due to delay in approval of technical positions resulting in further delays of hiring technicians in addition to delay in identifying qualified individuals. The students who were on 35-40% assistantships had considerable delays in implementing experiments due to delays in purchase of ORAC equipment. These delays also had impact on the rate of expenditure. There were no changes in approved objectives, methods and protocols. However we have applied for a no-cost extension of the project to give us more time to complete project objectives.

Impacts

A. H-ORAC values were 462-1420 umol in dry peanut skin, L-ORAC was 157-1336 umol and TAC was 722-2589 umol. Maximum TAC was obtained at 135 C, 5 min for GA (1699 umol) type only. Heated GA skins had higher H-ORAC (908 umol), L-ORAC (580 umol) and TAC (1488 umol) compared to TAC of grape skins (70-103 umol) and green tea leaves (236-1197 umol). Heating significantly increased the TAC of GA skin extracts compared to untreated raw GA skins; heating decreased the TAC of VA skin extracts; and severe heating (i.e >175 C) decreased TAC of SP skins. GA skins had highest antioxidant capacity with better radical quenching and reducing properties compared to VA or SP types. B. Combined US and UV increased resveratrol 4.9-12 fold (1.9 - 4.2 ppm) and total stilbenes 2.5- 6.5 fold (2.1 - 4.5 ppm) compared to untreated chopped peanuts (0.3 ppm, 0.6 ppm respectively). Resveratrol of 4.5-5 ppm can be achieved when chopped peanuts are exposed to US for 6.7-7 min and UV for 33-40 min. C. UV increased (78-234%) ORAC (53.4-100.1 umol) of some treated samples compared to untreated sliced peanuts (29.9 umol). Highest ORAC (100.1 umol) was achieved by exposing to UV for 30 min at 40 cm distance and incubation for 24h. Sliced peanuts with 42-53 umol and acceptance rating 5 or more

(not disliked) can be achieved using ID=37 to 40 cm, IT=10-30 min and IC=24-25.5h. D. US increased ORAC of sliced and some chopped but not whole peanuts. ORAC of US treated sliced peanuts ranged from 50.0-97.9 umol (40- 174% increase); chopped 42.7-91.1 umol (20-156% increase) and whole 26.2-51.6 umol (0- 45% increase) while untreated whole peanuts had 35.6 umol. An acceptable sliced peanuts (hedonic rating of 6 and more, liked slightly) with 50-93 umol can be achieved using US PD=75 mW/cc, PT=6.5-8 min; and IC=24-36h. These ORAC values translate to 852-1585 umol TE/serving of a peanut bar and 1420-2783 umol TE/serving of a peanut butter containing peanuts enhanced with functional compounds, which is 42 to 79% and 67-104% respectively of a serving of red wine. E. All US, UV, US-UV and UV-US treatments increased resveratrol 60-80 fold compared to untreated raw peanuts (0.05 ppm). The order of stress application, of US and UV had no effect on resveratrol and piceid concentration. Resveratrol in UV-US and US-UV combined treatments (4.3 and 4.6 ppm respectively) were not different ($P<0.05$) from peanuts treated with only US (3.9 ppm) or UV (4.4 ppm). F. Recovery of peanut extracts for piceid was 101-140%, and for resveratrol 79-107%. The CV (precision) for piceid, resveratrol and phenolphthalein were 1.5, 1.9 and 2.2%, respectively. The LOD and LOQ were 0.0125 and 0.0125 ppm; and 0.05 and 0.05 ppm; for piceid and resveratrol, respectively. G. UV time and distance had no effect on resveratrol concentration (2.1 - 4.7 ppm). Maximum concentration (4.7 ppm) was obtained when peanuts were US treated followed by UV for 35 min at a distance 40 cm. US alone produced high (4.3 ppm) resveratrol, suggesting that it can be an effective elicitor. US processing of peanuts can be used to maximize resveratrol, in food ingredients to enhance health benefits.

Publications

- No publications reported this period

Progress 07/01/06 to 06/30/10

Outputs
OUTPUTS: A. Peanut Kernels (PK). Of 27 treatments of varying distances from UV light (ID), UV exposure (IT) and incubation (IC) times in sliced PK, most increased trans-resveratrol (RES) to 3.3ppm, trans-piceid (PIC) 1.1ppm, total phenolics (TP) 1.8mg gallic acid equivalents (GAE)/g, trolox equivalent antioxidant capacity (TEAC) 3.4microM trolox equivalent (TE)/g, & oxygen radical absorbance capacity (ORAC) 100 microM TE/g; untreated controls had 0.02ppm, 0.03ppm, 0.8mgGAE, 0.6microM TE/g & 26.8microM TE/g, respectively. Overall acceptance (OA) rating of 5.8 (6=like slightly) & roasted peanutty flavor were lower, while off-flavors (astringent, bitter, & oxidized) were higher than controls, OA 7.4 (7=like moderately). Of 27 treatments each on sliced, chopped & whole PK, of varying ultrasound (US) power densities (PD), exposure (PT) & IC times, most respectively, increased RES to 6.4, 2.6 & 1.0ppm; PIC 6.4, 2.4 & 2.6ppm; TP 1.9, 1.8 & 1.8mgGAE/g; TEAC 3.2, 3.0 & 3.2microM TE/g; ORAC 97, 91 & 75microM TE/g; OA were 5.4, 5.2 & 5.3 (5=neither like nor dislike). Of 27 combined US-UV treatments of varying PD, PT & IT and fixed ID & IC in sliced PK, most increased RES to 7.1ppm, PIC 2.9ppm, TP 1.7mgGAE/g, TEAC 4.2microM TE/g & ORAC 220microM TE/g; OA was 5.6. p-Coumaric (226 ppm), ferulic (4.62 ppm) and caffeic (2.18 ppm) acids also increased. Process optimizations using response surface methodology, showed optimum UV, US & US-UV process parameters, respectively, produced highest RES of 2.1, 3.8 & 4.8 ppm & ORAC of 55, 75 & 150microM TE/g. Optimum US-UV processes included all process combinations within the area of a hexagon bound by PD 74, 70, 62, 42, 48 & 58 mW/cc for 8.3, 10.9, 11.2, 10.4, 8.3 & 9.1 min PT, followed by 50 min IT at 40 cm ID and 36h IC. B. Peanut Skins (PS). Varying heating time and temperatures in 15 treatments of PS from Runner (RU), Virginia (VA) & Spanish (SP), resulted respectively in TP of 101-280, 107-149 & 96-137 mgGAE/g; TEAC 1.23-2.56, 0.93-1.69 & 0.92-1.74 milliM TE/g; & ORAC 710-1699,

588-1154, 552-1371 microM TE/g; controls had 127, 123 & 128 mgGAE/g TP; 1.38, 1.30 & 1.50 mM TEAC/g; & 550, 939 & 780 microM TE/g ORAC, respectively. A method for simultaneous analysis of 15 phenolic compounds using reverse phase high performance liquid chromatography (RP-HPLC) was developed, validated and used for heat-treated PS extracts (PSE). RU, VA & SP had 162, 176 & 119 ppm protocatechuic acid; 4.7, 3.3 & 18.6 ppm caffeic acid; 27, 26 & 29 ppm p-coumaric acid; 312, 457 & 570 ppm catechin; 185, 130 & 280 ppm epicatechin; 174, 105 & 161 ppm quercetin; & 7.5, 6.1 & 24.3 ppm RES, respectively. Shelf life of soybean oil with 200 & 300 ppm PSE stored for 16d at 60C produced lower hexanal compared to 100 ppm PSE & 200 ppm TBHQ. PSE of 75, 200 & 400 ppm in mayonnaise stored up to 82d at 23C had hexanal not different from untreated control. PSE of 500 ppm in refrigerated cooked beef patties stored for 7d at 4C controlled hexanal effectively compared to 100 & 300 ppm. Results of this project were published in 2 PhD dissertations, 1 MS thesis, 8 journal articles and 15 poster papers, and presented in 10 lectures in national & international conferences. PARTICIPANTS: Anna V.A. Resurreccion, Professor, was the principal investigator of this project. TARGET AUDIENCES: The peanut processing industries will benefit from the knowledge of processing and the value-added product technologies; and consumers who will obtain the health benefits from bioactive-enhanced peanut kernels and skins developed in this project PROJECT MODIFICATIONS: Not relevant to this project.

Impacts

A. Peanut kernels are a rich food source of resveratrol next to red wines and grape skins. UV increased RES by 165-fold, PIC 3.3, TP 2.2, TEAC 5.7, and ORAC 3.7, compared to untreated controls. Slicing produced highest RES, PIC and ORAC but equal TP and TEAC, compared to chopping and whole US-treated PK. Combined US-UV treatment obtained highest RES, PIC, TEAC and ORAC but equal TP, compared to US and UV treatments. Optimum US-UV processes produced 1.6 and 2.3x greater RES; and 2.0 and 2.6x higher ORAC but equal TEAC and lower TP compared to optimum US and UV processes, respectively. Slicing increased RES by 19x from 0.02 ppm in control whole PK to 0.37 ppm in sliced PK. RES of sliced peanuts was further enhanced by UV to 3.3 ppm (8x); or by US to 6.4 ppm (16x). With US-UV, further increases to 7.14 ppm (18x) RES, suggested slight incremental increase due to UV over US alone. Significant new findings on enhancing resveratrol and phenolic antioxidant compounds in PK will provide information to peanut processing food industries to manufacture functional food with health benefits for consumers. Application of resveratrol enhanced peanuts (REP) in peanut bars (30g/50g-bar) were acceptable up to 5 months storage at 25C with slight reduction in RES from 2.10 to 1.28 ppm, TP from 1.8 to 1.48 mg GAE/g, and TEAC from 6.12 to 5.46 microM TE/g. On a per serving basis, about 3.5 peanut bars with initial 2.10 ppm RES will provide equivalent concentrations in a140 mL serving of red wine. Applications of REP such as in peanut bars and other resveratrol-rich functional foods will provide new product lines, increased value and profitability for the peanut processing industries. B. Peanut skins are a rich source of phenolic compounds. Heating PS resulted in higher TP, TEAC and ORAC compared to raw with Runners resulting in highest amounts than Virginia and Spanish. Generally, only mild heat treatments (greater than 135C, 15 min) could further enhance antioxidant capacity (AOC) of raw PS. Minimal heat treatment or no further heating is needed to maximize extraction of functional compounds from commercial peanut skins. With increasing interest in peanut skins as a rich source of antioxidants, the RP-HPLC procedure for simultaneous analysis of 15 phenolic compounds developed in this study could meet the demand for timely information on health promoting compounds in peanut skins. Peanuts with skins will increase intake of beneficial phenolics. Midlly heated SP peanut skin extracts (PSE) had highest concentrations of phenolic compounds compared to RU and VA. PSE concentrations of 200-300 ppm protect bulk oils from oxidation more effectively than 100 ppm PSE and 200 ppm TBHQ. At 7d storage, 500 ppm PSE decreased the rate of oxidation of beef patties compared to control. Natural food components such as PSE have high TP and AOC that may protect cells from reactive oxygen species and oxidative damage without using synthetic antioxidants. Utilization of peanut skins as a value-added by-product for developing dietary antioxidant ingredients, exhibits

high potential as a source of renewable raw material for functional food ingredients and is encouraged for food systems.

Publications

- 1. Francisco, M.L.dL. 2009. Functional components in peanuts. Ph.D. Dissertation. University of Georgia, Athens, GA. 336 pp.
- 2. Sales, J. M. S. 2010. Processes to enhance trans-resveratrol in peanut kernels and their optimization. Ph.D. Dissertation. University of Georgia, Athens, GA. 349 pp.
- 3. Potrebko, I. 2009. The Effect of UV doses in Combined UV-Ultrasound Treatments on Resveratrol and Piceid content in Sliced Peanut Kernels. Lund University, Lund Sweden. 25 pp.
- 4. Sales, J.M. and Resurreccion, A.V.A. 2010. Phenolic profile, antioxidants, and sensory acceptance of bioactive-enhanced peanut using ultrasound and UV. Food Chem. 122:795-803.
- 5. Resurreccion, A.V.A. and Sales, J.M. 2010. Phenolic profiles and antioxidant capacities of bioactive-enhanced peanuts treated using ultrasound and UV light (Abstract No. 237-06). Institute of Food Technologists Annual Meeting, Chicago, IL. July 2010.
- 6. Potrebko, I. and Resurreccion, A.V.A. 2010. Resveratrol-enhanced peanuts: antioxidant capacity and consumer acceptance (Abstract No. 193-17). Institute of Food Technologists Annual Meeting, Chicago, IL. July 2010.

Progress 07/01/06 to 07/01/07

Outputs

(A)UV irradiation of sliced peanuts using irradiation times (IT) of 10, 20, and 30 min at distances(ID) from a UV lamp of 20, 40, and 60 cm, and incubating at 25C for 24, 36 and 48h, significantly (alpha < 0.05) increased Total Phenolics (TP) and Antioxidant Capacity (AOC). The TP of UV-treated peanuts of 1.35-1.94 mg Gallic acid equivalent (GAE)/g and AOC of 2.34-3.48 micromoles Trolox equivalents (TE)/g were significantly higher than controls. ID was the significant factor affecting the TP in the UV-treated peanuts. TP obtained was similar to that of fresh blueberries and red wine. (B) Ultrasound treatments (US)using power densities (PD) of 25, 50, and 75 mW/cc for 4, 6, and 8 min (IT) and incubation at 25C for 24, 36 and 48 h, increased TP and AOC of chopped, sliced, and whole peanuts. TP of US treated chopped peanuts was 0.61-1.08 mg GAE/g; sliced 0.54- 1.18 mg GAE/g; and whole 0.64-1.01 mg GAE/g as compared to untreated controls. AOC in umoles TE/g of chopped peanuts was 2.09-3.22; sliced 2.15-3.21; and whole 1.99-3.13. (C) Combined US and UV treatments using PD of 25 mW/cc for 1, 4, and 7 min; and UV IT of 10, 25, and 40 min at ID of 40 cm; incubation at 25C, 24 h increased the TP to1.56-1.83 and AOC of 4.68-5.06 in chopped peanuts compared to controls. Ultrasound process and UV irradiation times were the significant factors in increasing TP and AOC. The highest TP of 1.83 and highest AOC of 5.07 were obtained when peanuts were treated with US 4 min and UV 10 min. (D) Three types of raw peanuts were heated at varying times and temperatures and skins were collected for analyses. Skins of Runner peanuts revealed total phenolics (in mg Gallic acid equivalent, GAE) of 101.43-231.10 mg/g; Virginia 106.60-148.84 mg/g; and Spanish 95.56-147.79 mg/g. The results of this study revealed maximum total phenolic content at least twice as compared to those reported in the literature. For example, maximum yield of only 118 mg/g dry peanut skins from dry-blanched Florunner (conditions not specified) was obtained under similar extraction conditions. Similarly, total phenolics of raw and roasted peanut skins at 175 C, 5 min (type not specified) were only 130.80 and 124.30 mg/g dry skin, respectively. The values obtained for all treatments across all types were found significantly higher than well known food sources for antioxidants (values range from 5 to 120 mg/g) such as green and black tea, rose

petal teas, grape seeds and skins, cocoa, blueberries and blackberries. Peanuts skins from this study remain unsurpassed by other food sources in scavenging capacity. Reported Trolox values of blueberries and blackberries were 0.028 and 0.020 mM/g, respectively; rose petal teas were reported to have Trolox values ranging from 0.71 to 1.77 mM/g while green tea has a Trolox value of only 1.23 mM/g. The comparative study of total phenolics and antioxidant capacities of peanut skin extracts from the three types and other food sources confirm the potential of peanut skins as an alternative source of functional compounds. Sensory tests on UV, US, and UV-US treated peanuts and identification of functional components in FP and peanut skin extracts is onging.

Impacts

These studies result in recommendations for development of processing technologies for peanuts to obtain Functional peanuts and peanut skins with increased levels of phenolic compounds and antioxidant capacity. The resulting functional peanuts can subsequently be used as ingredients in various food products, snacks and spreads with beneficial phenolic and antioxidant compounds. The comparative study of total phenolics and antioxidant capacities from peanut skin extracts confirm the potential of peanut skins, a low-value by product of the peanut processing industry, as an alternative source of functional compounds. Peanuts skins from this study remain unsurpassed by other food sources, including green tea and blueberries in anti-oxidant capacity. Application of these technologies to peanut kernels and skins will result in increased beneficial compounds associated with prevention of the risk of cardiovascular diseases, cancer, and Alzheimer's disease.

Publications

- No publications reported this period