Elliger, C. A., Waiss, A. C., Lundin, R. E., *Phytochemistry* **13**, 2319 (1974).
Elliger, C. A., Waiss, A. C., Lundin, R. E., *J. Chem. Soc., Perkin Trans. 1*, 2209 (1973).
Miller, R. E., Edwards, R. H., Kohler, G. O., *J. Am. Oil Chem. Soc.* **56**, 556 (1979).
Murray, J. V., Cloke, J. B., *J. Am. Chem. Soc.* **56** 2749 (1934).
Nelson, E. A., Trei, J. E., Verbiscar, A. J., Banigan, T. F., "Palatability of Various Jojoba Meal Preparations with Lambs", Western Section, Am. Soc. Anim. Sci., University of Arizona, Tuscon, Jul 28–Aug 1, 1979.
Payne, G. B., Williams, P. H., *J. Org. Chem.* **26**, 651 (1961).
Radziszewski, B., *Ber. Dtsch. Chem. Ges.* **17**, 1289 (1884).
Reid, B. L., personal communication, 1977.
Temple, M. K., M.S. Thesis, California State Polytechnic University, Pomona, CA 1979.
Trei, J. A., Nelson, E. A., Verbiscar, A. J., Banigan, T. F., "Evaluations of Deoiled Non-detoxified Jojoba Meal with Lambs", Western Section, Am. Soc. Anim. Sci., University of Arizona, Tucson, Jul 28–Aug 1, 1979.
Verbiscar, A. J., Banigan, T. F., *J. Agric. Food Chem.* **26**, 1456 (1978a).
Verbiscar, A. J., Banigan, T. F., Weber, C. W., Reid, B. L., Trei, J. E., Nelson, E. A., "Detoxification and Analysis of Jojoba Meal", Proceedings, Third International Conference on Jojoba, Sept 13–16, 1978, at University of California, Riverside, pp 185–197.
Verbiscar, A. J., Banigan, T. F., "Jojoba Seed Meal as an Animal Feed", Proceedings of a Conference, Non-Conventional Proteins and Foods, Oct, 18–20, 1977, University of Wisconsin, Publ. National Science Foundation, 1978b pp 63–76.
Wiberg, K. B., *J. Am. Chem. Soc.* **75**, 3961 (1953).
Wiberg, K. B., *J. Am. Chem. Soc.* **77**, 2519 (1955).

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Total Glycoalkaloids in Potatoes and Potato Chips

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The process of chipping under the conditions employed was found to be nondestructive to total glycoalkaloids (TGA) and resulted in the concentration of TGA. Removal of the potato peel from the potato slices significantly lowered the TGA content of the finished chips. Three samples of commercial chips were found to contain from 9.5 to 72 mg of TGA/100 g of chips.

Tubers of the potato plant, *Solanum tuberosum* L., contain a low level of glycoalkaloids, a class of naturally occurring toxicants. The primary constituents of this class of compounds in potatoes are α-solanine and α-chaconine, which are glycosides of the steroidal alkaloid solanidine. A total glycoalkaloid (TGA) content of 20 mg/100 g of raw potato is widely accepted as the upper limit for these compounds, both due to the potential health hazard and to the fact that they can impart an undesirable bitter flavor at higher concentrations (Jadhav and Salunkhe, 1975).

The concentration of TGA is affected by many environmental factors. Exposure to UV light, low-temperature dark storage, and mechanical damage particularly stimulate the potato to increase synthesis of TGA (Jadhav and Salunkhe, 1975; Wu and Salunkhe, 1976). Salunkhe et al. (1972) demonstrated that light and elevated temperatures dramatically increased solanine synthesis in peeled potato slices incubated for time intervals up to 48 h.

The highest concentration of TGA in the potato are found in the skin, eyes, and sprouts. Zitnak (1961) reported that the outer 3 mm of the potato contained approximately half of the TGA; however, it represented only 14% of the total weight of the potato.

Extensive literature exists concerning TGA content of raw potatoes; however, very little information is available concerning TGA in processed potato forms. Both α-solanine and α-chaconine have been reported to be heat stable (Jadhav and Salunkhe, 1975) upon instantaneous exposure to high temperature. However, the time factor was not considered. Porter (1972) has reported that these compounds decompose in the 260–270 °C area, which is 70–80 °C above normal commercial frying temperatures. Also, it is possible that potato processing involving the removal of water could elevate TGA concentrations thereby creating either a health hazard or an undesirable flavor. This project was undertaken to determine the effect of chipping on TGA concentration of potato slices as well as measure TGA levels in commercial chips.

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EXPERIMENTAL SECTION

Sampling and Potato Chipping Procedures. Norchip potatoes, harvested July 8 near Phoenix, AZ, were chipped July 11 in Fort Collins, CO. The potatoes had been shipped directly via unrefrigerated carrier and were stored in crates (2000-lb capacity) at ambient temperatures until processed.

Approximately 50 kilos of potatoes were sorted according to size and then redistributed into five groups in such a manner that each group had the same number and size distribution of potatoes. One set of potatoes was retained for compositional analysis, and the remaining four groups were chipped.

Sampling of raw unpeeled potatoes was done by the method of Fitzpatrick and Osman (1974). A portion of potatoes was manually peeled to remove the outer 1–2 mm of skin and sampled using the previously mentioned sampling procedure of Fitzpatrick and Osman (1974). The peels (~12% of the total potato) were chopped in a Waring blender and then immediately sampled. The above procedure was used to provide control TGA data on the raw whole, peeled, and peel potato.

The potatoes were chipped using a sequence designed to simulate commercial chipping operations: (1) Each group was scrubbed lightly to remove surface dirt. (2) The potatoes were peeled in a Hobart abrasion peeler (this step was omitted for sample D which was not peeled). (3) The

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Table I. Chipping Data

sample code	frying temp, °C	fry time, min	% peeling loss	slice thickness, mm	chip yield/ 100 g of raw washed potato slices	% oil in chips	% water in chips
A	153	6.5	3.82	1.6	30.7	42.0	1.18
B	167	5.0	3.60	1.6	27.3	37.3	1.42
C	181	4.0	4.16	1.6	27.3	27.3	1.37
D	181	4.0	0	2.2	26.0	26.0	1.48

Table II. Total Glycoalkaloid Concentration of Potatoes Used for Making Potato Chips

sample	total glycoalkaloid concn, mg/100 g of fresh wt[a]
whole potato	4.23 ± 0.20
manually peeled potato	2.37 ± 0.64
potato peel (manual)	10.8 ± 2.4

[a] Mean values and standard deviation of the mean.

Table III. Total Glycoalkaloid Concentration of Experimental Chips

sample code	total glycoalkaloid concn, mg/100 g of chips
A	14.2 ± 0.9
B	12.3 ± 2.3
C	16.1 ± 2.1
D	23.6 ± 1.5

[a] Mean values and standard deviation of the mean.

Table IV. Total Glycoalkaloid Concentration of Commercial Potato Chips

sample code	total glycoalkaloid concn, mg/100 g of chips
A	72.0
B	9.55
C	9.50

potatoes were sliced to the appropriate thickness using an Eagle Food Machine Company potato slicer. (4) Two kilograms of the slices was soaked for 3 min in 3 L of tap water to remove surface starch. (5) The slices were drained for 30 s and then immediately chipped in a Hotpoint fryer filled with a partially hydrogenated soybean oil. (6) The finished, unsalted chips were cooled, crushed, and mixed well to make sampling more uniform.

Analyses. TGA analyses were performed by the nonaqueous titration method developed by Fitzpatrick and Osman (1974). Three replicate analyses were conducted in each sample. Oil levels were determined using a Goldfinch extraction (7 g of chips extracted with 100 mL of ether for 12 h). Moisture content was determined using a Cenco moisture balance.

RESULTS AND DISCUSSION

The chipping data are presented in Table I. The potato slices were fried to a bubble end point to determine the frying time. As can be seen from the moisture analysis, the finished chips were quite uniform, ranging from 1.18 to 1.48% water. Absorption of oil was inversely related to frying temperature as could be expected. The thicker sliced chips with peel (sample D) were quite similar in composition to the thinner sliced chips without peel. Abrasive peeling losses were lower than normal since the Norchip potatoes used had a very easily removed, thin peel (specific gravity of 1.067).

The TGA concentrations and distribution in manually peeled potatoes (see Table II) were similar to those previously reported (Gull and Isenberg, 1960). The skin contained four times the TGA as the interior portion of the potato. However, the manual removal of the potato skin resulted in a much higher peel loss (12%) than that of the mechanical Hobart peeler.

The finished chips had TGA concentrations in the range of 12.3–23.6 mg/100 g (Table III). The latter value exceeded the threshold values reported to impart a bitter flavor, but this flavor was not noticeable in the chips.

Normally, 3–4 lb of raw potatoes will yield 1 lb of finished potato chips. Most of the weight lost is the water removed during frying although solids are lost due to both peeling (4–8%) and washing (2.5%) of the sliced potatoes. Oil absorption by chips will account for 32–40% of the weight of the finished chip. Overall, the chipping process resulted in a three–four-fold concentration of substances found in the raw potato.

The thick sliced potato chips made utilizing the potato with skin (sample D, Table III) were markedly higher in TGA's than other experimental chips. This difference was due entirely to the high glycoalkaloid content of the skin, which was incorporated in the chips.

Commercial potato chips purchased from local supermarkets were found to vary widely in TGA concentration (Table IV). Samples A and B were "regular" chips, while sample C was marketed as "thick sliced" and made from unpeeled potato slices. Sample A was unexpectedly high in TGA while sample C was unexpectedly low. Close examination of sample A chips revealed that 75–90% of the skin remained in the chips, thus contributing to this high value. Although it had a high TGA content, the taste of sample A was normal, having no noticeable bitterness. Perhaps the presence of significant amounts of oil and salt in the product had a masking effect.

LITERATURE CITED

Fitzpatrick, T. J., Osman, S. F., *Am. Potato J.* **51**, 318 (1974).
Gull, D. D., Isenberg, F. M., *Proc. Am. Soc. Hort. Sci.* **75**, 545 (1960).
Jadhav, S. J., Salunkhe, D. K., *Adv. Food Res.* **21**, 307 (1975).
Porter, W. L., *Am. Potato J.* **49**, 403 (1972).
Salunkhe, D. K., Wu, M. T., Jadhav, S. J., *J. Food Sci.* **37**, 969 (1972).
Wu, M. T., Salunkhe, D. K., *J. Am. Hort. Sci.* **10**, 329 (1976).
Zitnak, A., *Can. J. Biochem. Physiol.* **39**, 1257 (1961).

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