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(1)

TREE NUTS Production Processing Products

Volume One

Almonds — Brazil Nuts — Cashew Nuts
Chestnuts — Filberts — Macadamia Nuts

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THE AVI PUBLISHING COMPANY, INC.

1967

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Courtesy Keith Thomas Co.

FIG. 16. ALMOND BUTTERSCOTCH CAKE

Hess (1925) published 800 favorite pecan recipes, which were selected from 21,000 recipes submitted by 5,083 women from over the world. The recipes cover every phase of every meal planning, for all seasons of the year. They are grouped under the following headings: pecan yeast breads, pecan quick breads, pecan cakes, pecan candies, pecan desserts, pecan entrees, pecan pies and pastries, pecan salads, pecan sandwiches and pecan relishes. Included are miscellaneous recipes not covered above, such as pecan powder, pecan mincemeat, and pecan okra soup. Each of the recipes were calculated for a meal of a family of four.

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Roasting and Salting Nuts

INTRODUCTION

Salting is the largest outlet for tree nuts, because a major portion of all of them, except chestnuts, are eaten in this form. Most imported nuts—cashews, pistachios, macadamias, as well as Brazil nuts and pine nuts—are roasted in the shell and eaten without salt; more pecans are used in bakery products than are salted, and more almonds go into confections.

Nuts are roasted (toasted) for salting either dry, or in oil. They are dry roasted by radiant heat or microwaves. Each of these may be in batches or continuous. Before roasting the meats should be graded for size, color and imperfections; separated from shells and other foreign material; and sometimes counted.

Salted nuts are among the rapidly increasing snacks. The low price keeps the market broad—with a strong appeal to teenagers. The variety and season is equally broad. Indoors they are eaten during television, radio and party activities; and outdoors they have become a part of athletic events, barbecues, picnics and camping.

Nut salters are becoming fewer but larger. Because of better-than-average profits and relative low initial outlay, the industry is dominated by regional companies. To compensate for high labor and material cost, nut salters have turned to automation and quantity production. Companies

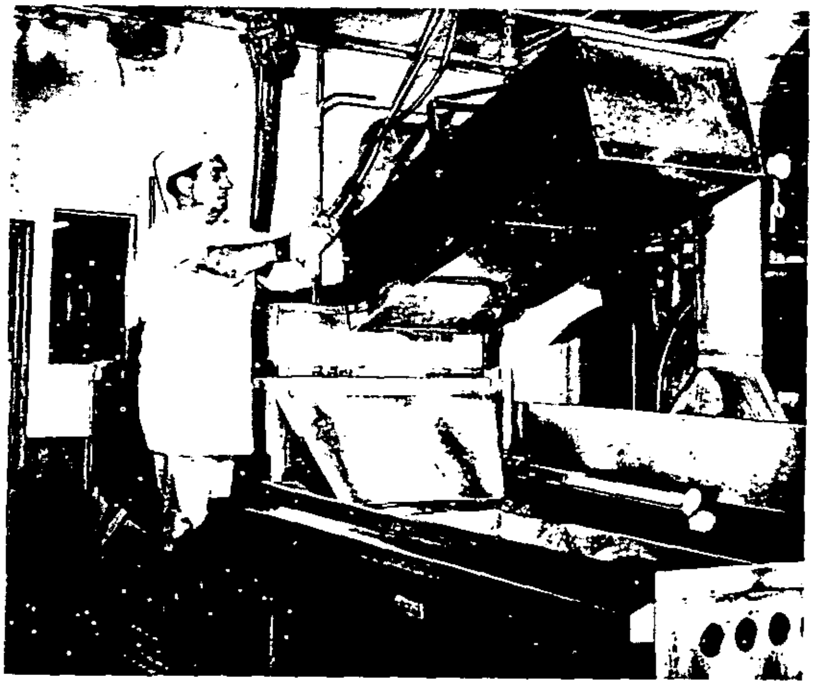
PROCEDURE

The following are eight steps for salting nuts.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Roast at 250°–350°F.	Cool to 150°F	Apply oil dressing with antioxidant	Apply salt with antioxidant	Cool to 110°F.	Apply "shine" oil	Allow to set	Package
Use coconut or other low melting oil. It should melt at about 70°F and solidify at about 80°F. The time varies from 5–25 minutes, depending on the kind and size of nuts.	Use forced air through bottom of vat.	Make first application of low melting (65°–70°F) coconut or other oil at 150°–200°F by spraying.	Sprinkle with 2% of fine flake salt and stir thoroughly.	Use forced air through bottom of vat.	Spray on and stir gently to "seal on" salt.	Hold 1–3 hours to allow volatiles to escape, the dressing to set and the oil on surface to equalize.	This may be under vacuum in glass or tin containers, in small flexible bags or in bulk.

are consolidating and serving larger areas, even overseas markets. They are also capitalizing on more leisure at home.

Bauer Brothers Company is responsible for engineering and constructing much of the equipment now used in nut processing. The Company started small in 1878, as the Foos Manufacturing Company. In 1904 the Company was bought by Bauer Brothers, and by 1918 was making seed cleaners, various types of hullers, separators, shakers and attrition mills.



Courtesy Calif. Almond Growers Assoc.

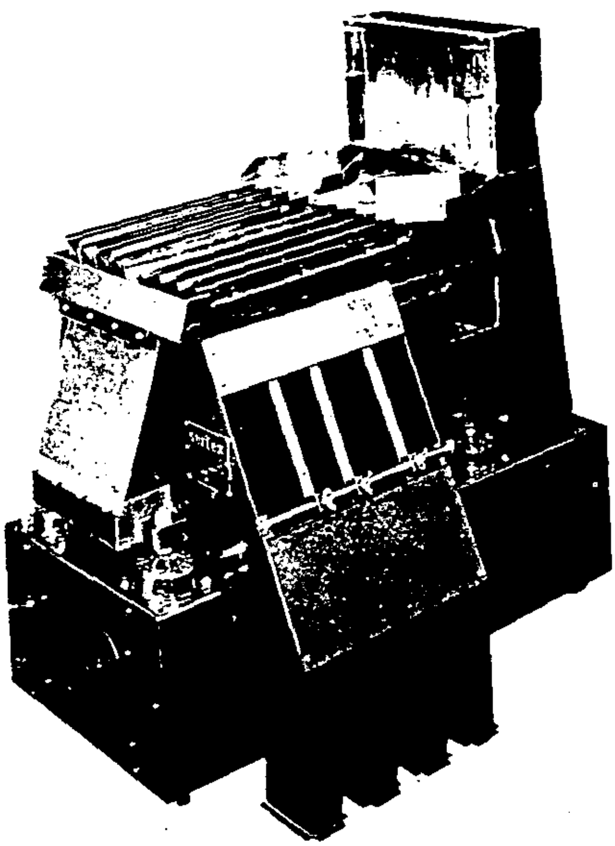
FIG. 17. OIL ROASTING NUTS FOR SALTING

One hundred pounds of selected nuts are loaded into the basket and lowered into boiling oil until a crisp texture and golden color is reached. Subsequently the nuts are drained, centrifuged to remove excess oil, and given a dressing of seasoned salt.

The Company expanded in research and development and in 1933 the first peanut butter mill was designed. Following closely was the development of a complete line of roasters, coolers, blanchers, separators, picking tables, granulators and "accessory" items.

The Meyer Machine Company, San Antonio, Texas, is the world's largest producer of edible nut processing equipment. The equipment includes automatic nut crackers, inshell nut graders, dial type shellers, cull and shrivel removers, washers and conditioners, floating machines, centrifugal extractors, vacuum pumps and tanks, nut meat cutters and breakers, and antioxidant-treating machines.

Some of the nut kernels processed for market and for various nut products are blanched (removal of skin or membrane covering the white meat). Almonds are soaked in hot water until the skin slips off readily; they are then dehydrated and may be immersed in hot peanut or coconut oil at 300° F. and salted to give the salted almonds of commerce. Hot-water treatment is not sufficient to loosen and remove the skins from the wrinkled surface of Persian walnuts, so the kernels of these nuts are blanched by immersion in hot lye solution followed by a dilute acid rinse; this process gives a white nonastringent product. Pecan meats are not blanched. An improved glycerin-alkali process for blanching almonds, filberts, Brazil nuts and other nuts, which preserves the flavor and texture of the nuts, consists in passing the kernels through a heated solution of 1 oz.

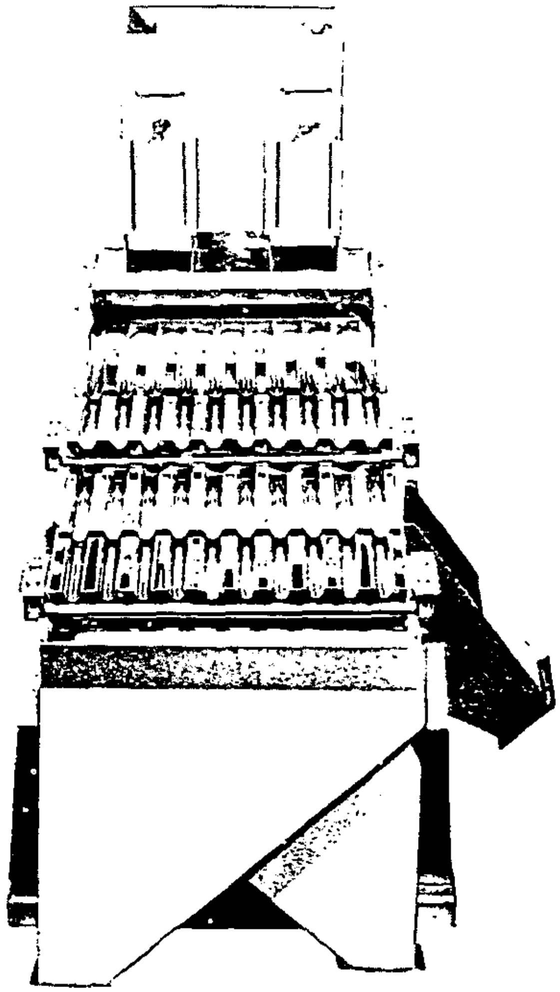


Courtesy Sortex Company

FIG. 18. POLYGRADER FOR NUTS

A British made unit for separating nuts into four grades.

glycerin and 6 oz. sodium carbonate per gallon water; removing the skins with a stream of water; and dipping the kernels in a weak citric acid solution to neutralize any alkali retained by the kernels (Leffingwell and Lesser 1946).

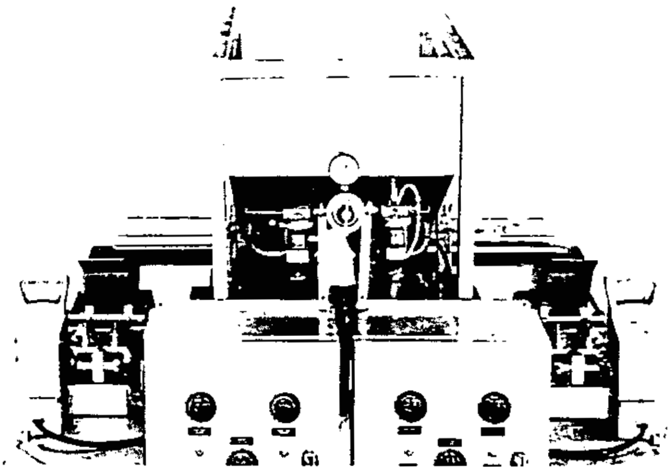


Courtesy Sortex Company

FIG. 19. FRONT VIEW OF AMERICAN MADE POLYGRADER FOR NUTS

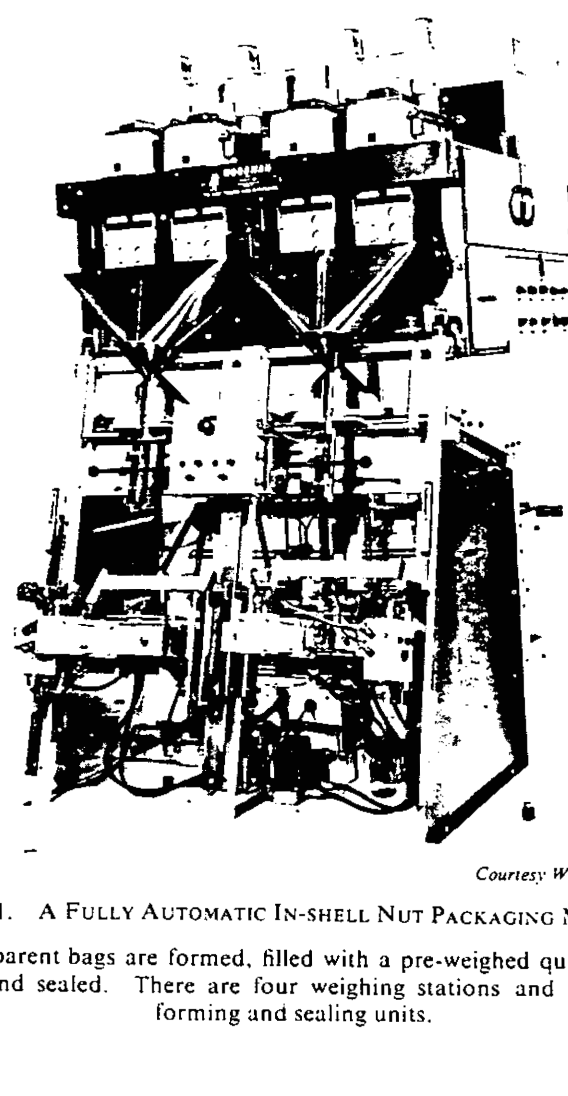
Specific Gravity Separator

One of the unique and most widely used machines in the nut industry is a specific gravity separator. This unit combines mechanical and pneumatic action to separate and classify dry materials of different or varying densities, sizes, consistencies or weights. It removes alien objects, imperfec-



Courtesy Exact Weight Scale Co.

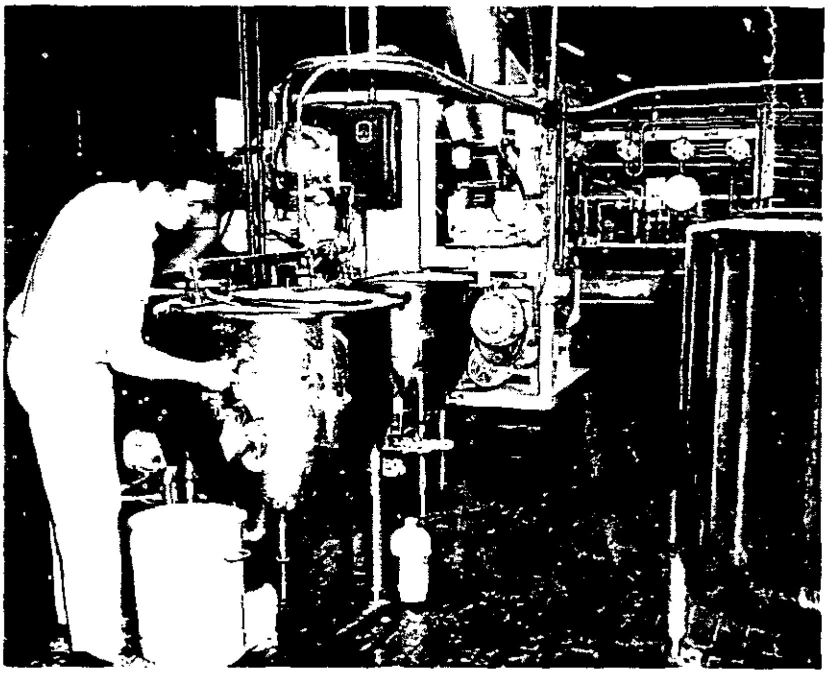
FIG. 20. AUTOMATIC WEIGHING MACHINE FOR NUTS AND CANDIES



Courtesy Woodman Co.

FIG. 21. A FULLY AUTOMATIC IN-SHELL NUT PACKAGING MACHINE

Transparent bags are formed, filled with a pre-weighed quantity of nuts and sealed. There are four weighing stations and two bag forming and sealing units.



Courtesy Wyandotte Chemicals

FIG. 22. RIGID SANITATION IS NECESSARY IN THE BAKERY

Much of the cleaning requires hand brushing and a good detergent. Here kettles are being cleaned and polished between shifts.

tions and impurities, thus guarding product quality and simultaneously protecting other equipment from possible damage by foreign materials (Anon. 1966D).

These separators are used for cleaning and/or separating such products as raw or roasted shelled or unshelled pistachio nuts, nut meats and products containing nuts. Pinon nuts are separated from pine needles, stones, dirt and other debris in these separators.

Magnetic Cleaner

Permanent, non-electric magnets are used for removing tramp metal, rust particles and similar foreign objects from nuts being processed. Included in the line-up are magnetic plates, grates, pulleys and traps as well as special magnets for picking tables or inspection tables. These versatile units are employed for wet, dry or liquid materials incorporated in chutes, ducts, spouts, hoppers, pipe lines, conveyor lines and in other places.

The magnets are specially developed non-metallic materials energized for intense concentration of holding power, for holding ferrous impurities before they can enter and damage machinery. The units are available in a wide range of sizes and types. Wing and drawer-type grate magnets are in

163 standard sizes in single and double bank models for use in hoppers and floor openings or closed chutes and ducts (Anon. 1962C).

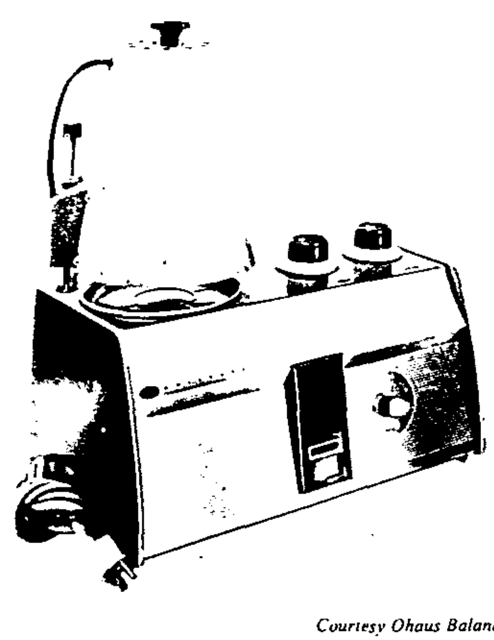
Nut Counter

One of the tests to determine grade of nuts is the count per pound. A unit has been developed for determining both an average seed weight and of weight variability. The counter eliminates manual counting, and utilizes a highly accurate electronic unit that counts peanuts and similar nuts at the rate of 250 to 750 seeds per minute, depending upon size and uniformity.

The weighed sample is poured into the open top of the unit. Vibration causes the nuts to travel in single file along a spiral track. This track discharges into a chute where the seed break a beam of light as they go downward. Interruption of the light beam is detected by a photocell which produces an electric pulse. The pulse is amplified by transistorized amplifier to operate high speed count register. The counter registers total count for each sample by convenient push button (Anon. 1962A).

NEW MOISTURE DETERMINATION BALANCE

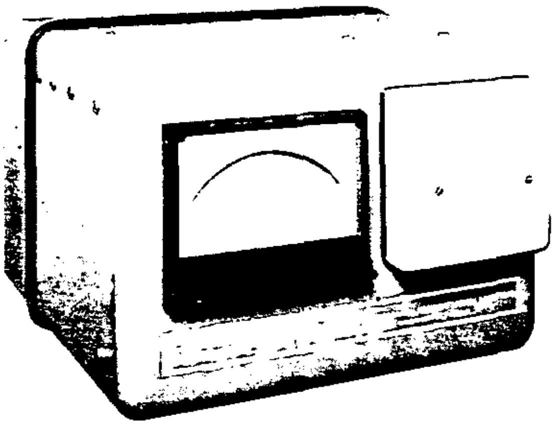
Fig. 23 shows a balance that provides automatic moisture determination with a full capacity, direct reading optical scale calibrated in both grams and per cent moisture loss. Solid or liquid material can be tested

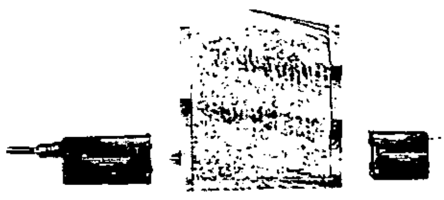


Courtesy Ohaus Balances

FIG. 23. AUTOMATIC MOISTURE DETERMINATION BALANCE

The sample of solid or liquid is dried with infrared heat, and moisture loss can be read at any time either in grams or per cent.





Courtesy Microwave Instrument Co.

FIG. 24. MICROWAVE MOISTURE METER FOR NUTS AND SIMILAR PRODUCTS, WITH INSET SHOWING SAMPLE BEING TESTED

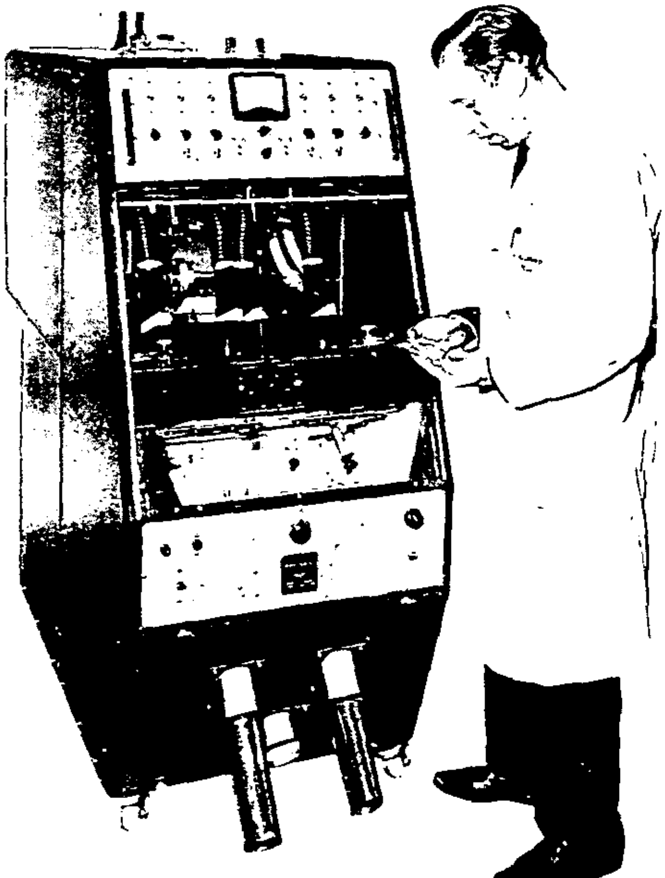
INSET FOR FIGURE 24. MICROWAVE MOISTURE METER

easily and moisture loss or weight of drying sample can be read directly throughout the entire drying cycle. No manual rebalancing is required. The heating unit is a standard tungsten filament infrared lamp. An automatic shut-off timer permits settings up to 60 min. in 1 min. intervals. The heat is shut off at any pre-set time. The balance uses disposable aluminum foil pan liners.

ELECTRONIC SORTERS

After nuts are shelled and all foreign material is removed from the meats, they are graded for color electronically by use of an "electric eye." This unit can be adjusted to separate the "wanted" from the "reject" nut meats wherever there is a difference in color. Photocells accurately and speedily identify and separate individual particles passing before them at the rate of more than 100 per second, per cell.

The selector is compact, simple to operate, and easy to maintain. There are only two moving parts, two counter-rotating rollers, which feed material particles single-file into the scanning head.



Courtesy Sortex Co.

FIG. 25. ELECTRONIC COLOR SORTING MACHINE

(1) Fiberglass airleg showing air outlet pipe on top for connection of dust extractor to remove lightweight foreign particles: dust and fine pieces: (2) compressed air filter and air reservoir which connect to air ejection: (3) optical box and ejector power supplies; (4) delayed ejection control; (5) compressed air input fitting; (6) electrical power input receptical; (7) feed chassis which contains motor driven feed belt and motor; and (8) blowthrough air duct.

Material is fed into a hopper from a holding bin and a vibratory feeder moves it in the desired volume onto the top end of the counter-rotating rollers. The nutmeats are scanned from two sides by two photocells. If the product is darker or lighter than the "set norm" a signal is given that is transmitted to the air valve which, in turn, ejects and pushes the bad particle out of its free flight path and down into the reject chutes (Anon. 1966D).

Through changes in optical filters in front of the photocells, and changes of background plates, at which the photocells "look," it is possible to adjust for whatever level of sort is desired. Smaller deviations from the set norm can be accomplished by panel controls.

Capacities vary in accordance with the percentage of damage in the feed, quality required, value of product, and nature of the product. For example, medium size pecan pieces vary from 200 to 500 lb. per hour. The selector is equipped with unit circuits which can be removed and replaced, in about two minutes in case of malfunction. Standard tubes and resistors

Courtesy Gromax Inc.

FIG. 26. ELECTRONIC PECAN SORTING MACHINE

This unit can handle sizes from midgets to halves, without making any mechanical changes on the machine. Changes can be made by emptying the hopper of the one product and dumping the other. The photograph shows two outlets for the sorted nuts and one on the left for collecting dust, meal and other fine particles before the sorting process. The light source is tungsten filament incandescent.

are used throughout. The unit is mounted on casters and weighs about 300 lb.

The operator can change from one product to another in about one minute. One attendant can supervise 50 or more machines and can be trained by in-plant instruction during the installation period (Anon. 1964).

HIGH FREQUENCY ROASTING

Nuts can be heated, roasted or "refreshed" by high-frequency waves. In commercial applications the shelf-life of peanuts heated to 180° F. is doubled. The high frequency heat waves sterilize the nuts, improve the flavor, and extend the shelf-life, by heating all the way through without over heating. Because of the high heating cycle, nuts can be processed fresh as needed.

Dielectric heating takes place between a pair of plates charged with high frequency current. Polar molecules in the product change position every time the polarity of the plates changes, and this generates heat by agitating the molecules (Manwaring 1966).

VERTICAL COOLER

A recently developed veritcal cooler reflects the nut industry's need for technological advancement, because it eliminates heavy manual labor, dangerous openings and rails in the floor and requires only one-fourth the floor space needed for the usual type of cooling equipment. The vertical cooler is totally enclosed and incorporates many production and sanitation innovations.

DRY ROASTING

Dry roasting of nuts is an outstanding example of the predominance of rule of thumb methods in the preparation of a food.

In general, as the internal temperature of the nuts increases, the processing changes occur more rapidly and become more complex. As compared with most fresh foods, nuts are low in moisture, usually varying from 7 to 4%; and when subjected to an internal temperature of 250° to 300° F., the moisture is reduced to about 1%. Other changes include destruction of a large portion of the thiamin, while niacin, choline and riboflavin are little affected by roasting (Higgins *et al.* 1941; and Pickett 1941, 1944, 1945; and Pickett and Holley 1952). Although the proteins are denatured as shown by the change in peptization in water, apparently their nutritive value is unchanged by moderate heat treatment, such as is used for blanching. Such constants of the oil as iodine number, saponification number, acetyl number, and free fatty acids do not change appreciably during the roasting process. Total sugars in nuts decrease when subjected to a heavy roast, while the starch and sulfur content is not significantly altered.

Batch Dry Roasting

There are many advantages in batch roasted nuts. The equipment is large and expensive to operate at less than capacity. On the other hand batch roasters are compact, fast, with high capacity and can be automated to provide the advantages of continuous operation without personal supervision (Anon. 1966).

The color control unit in each batch roaster assures uniform roasting and uniform color of the nuts. It actuates the pilot light, flame failure safety devices and the high temperature safety cut-off. It automatically charges the roaster from bulk or conveyor, discharges the unit, controls the cooler, and simultaneously provides a permanent record of temperature and time cycle.

By eliminating the possibility of human error, a key role is played in upgrading quality in the nuts. Nuts roasted by radiant heat are uniform in color and flavor. Burners inside the roaster cylinder uses natural, manufactured mixed, carburetted or compressed propane or butane gas.

The capacity of the automatic batch roaster is one ton or more per hour, depending on the kind of nuts and color desired. For "white" roast it is greater than dark roast; and for pecans it is greater than for peanuts or almonds.

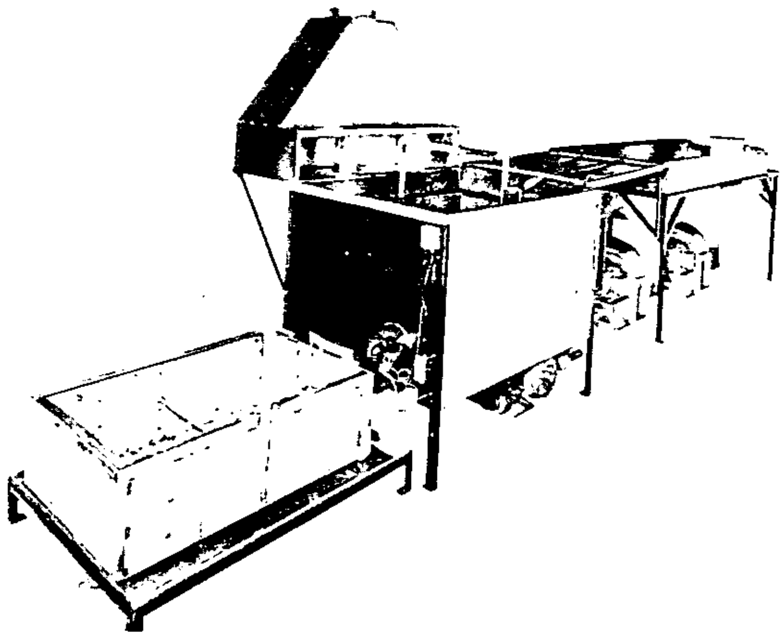
OIL ROASTING

Modern continuous nut roasters as shown in Fig. 28 are in use in America and European countries as well. Burns Fry-O-Matic continuous oil nut roaster and cooler is an example. This machine automatically roasts, cools, salts and glazes the product. It is economical to operate, with low fuel and maintenance cost, and no direct labor is required from the point of automatic feed to discharge except occasional supervisory attention. The time of immersion and temperature are accurately controlled so that each nut is subjected to the same amount of heat, and is immersed in oil for the same length of time.

One "3-bag nut roaster" has an extremely great rate of heat input—250,000 B.t.u./hr. The temperature of the roasting oil is restored to the initial temperature before the nuts are completely roasted, making it possible to induce succeeding batches of nuts immediately after the preceding ones have been removed from the roasting oil.

The batch roaster has a single roasting basket with a cooling table; or with a two basket setup, which includes a loading stand, roaster, drain table and a cooling table. With the two basket setup, basket number one is placed on the loading stand and filled with nuts, and is immersed into the oil when it is up to temperature. Basket number two is immediately filled with nuts. When basket number one is roasted it is removed from the roaster and placed on the drain table, and basket number two is placed in the roaster. When the nuts in basket number one are drained they are poured on the cooling table and the basket is returned for reloading.

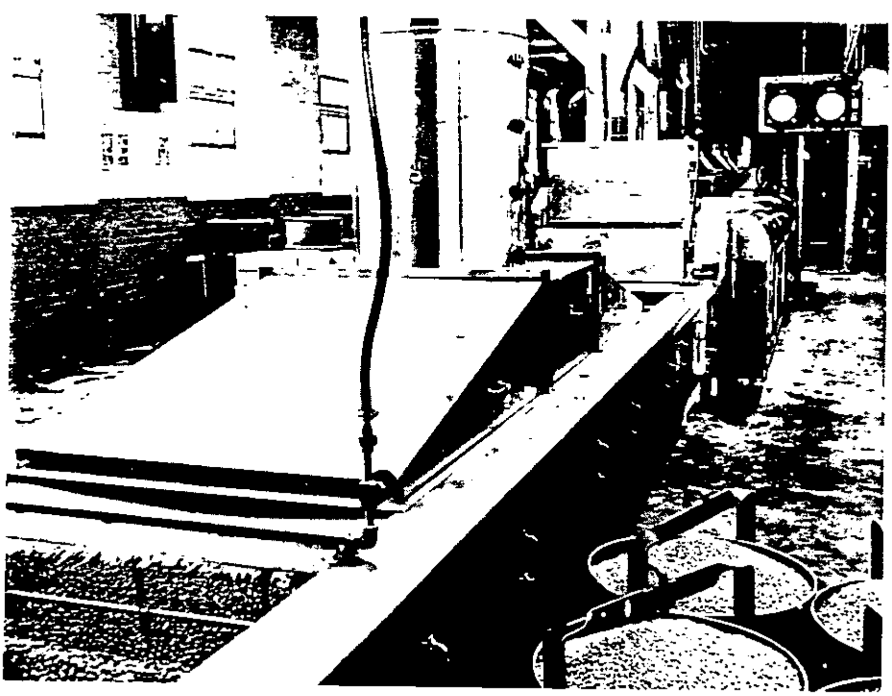
With the two basket setup, the roaster produces the maximum capacity with the highest possible rate of turnover (Anon. 1962B).



Courtesy Specialities Appliance Corp.

FIG. 27. THREE-BAG NUT ROASTER

This is a two-basket operation, as there is a basket on the loading stand and one basket in the cooker. Between the cooker and the cooling table is a drain table.



Courtesy Fry-O-Matic Co.

FIG. 28. INTAKE END OF FRY-O-MATIC OIL NUT ROASTER

Control of Color During Roasting

Control of color quality in nut roasting is becoming increasingly important as a means of quality control. But attempts to control objectively the color of non-homogeneous and parti-colored products have given problems. Parti-colored products are those colored with different tints. Since it is the color of the surface that is being measured grinding or dissolving are not satisfactory, and reflectance measurement is needed. Large samples are necessary to overcome variations when particles are rear ranged; and the illumination is by diffuse light.

A wide area viewer is designed to operate with 400 Agtron, to measure the relative spectral characteristics of parti-colored nuts. The Agtron principle utilizes pure monochromatic (one color) light to illuminate the sample. The light is obtained from two concentric gaseous discharge tubes —one mercury vapor and one neon—which radiate light at specific lines or wavelengths which have zero bandwidth.

These tubes are ionized by a regular high voltage power supply such that the tubes produce bursts of luminous energy at a 120-cycle rate. The spectral lines of energy occur principally at 435.835 *nm (nano-meter* 10^9 *m)*, 546.074 nm, 640.225 nm, and 585.248 nm. Interference filters are used to "isolate" these lines and phototube, which receives the reflected light, produces an output signal proportional to the luminous intensity.

Use of monochromatic light also permits shades-of-gray calibration standards. The meter reading is affected only by intensity without regard to spectral wavelength. Standardization consists simply of selecting the desired gray calibration disks and using two vernier controls to set the meter zero and full scale span. Thus, standardization and sensitivity are set simultaneously without the use of a colored reference and without complicated calibration procedures (Simmons 1966).

DEEP FAT FRYING

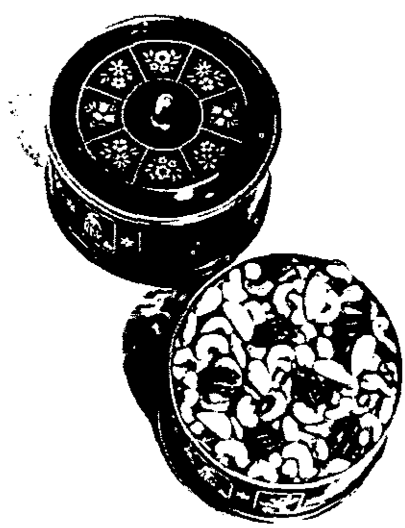
It has been shown that maximum sensory scores resulted when potatoes were deep-fat fried at 9½ minutes at 340° F., 8 minutes at 365° F., and 6½ minutes at 390° F. The absorption of fat was about the same for each of these conditions. The internal temperature of the potatoes rose to 216°-220° F. in 2½-3 minutes and remained throughout the cooking period. The steam pressure from within and the surface coating hindered further oil pick-up or change of internal temperature. Therefore, internal temperature could not be used as a criteria of doneness (Strock *et al.* 1966).

The following section was prepared by G. H. Scofield (1963) for the *Manufacturing Confectioner.*

The term "deep fat frying" is the processing of nuts by complete submersion in an edible fat heated to 250° to 350° F. The nuts are held in a basket or on a belt submerged in hot fat, which is in turn held in an open top holding tank. The nuts may be in a stationary position or conveyed through the heated fat until fried. They are removed from the fat, cooled, salted, and dressed with oil.

Why Deep Fat Fry Nuts?

Deep fat frying alters and substantially improves the flavor, texture, color and appearance of nuts from the raw state. In the case of most nuts the flavor changes from a "green," raw nut taste to the roasted flavor so much enjoyed. In the case of cashew nuts the raw nut is largely devoid of flavor, whereas the deep fat fried product has the characteristic mildly sweet cashew flavor.



Courtesy Rose Confections

FIG. 29. SALTED NUT MIX IN METAL CONTAINER

A choice of flavors and textures are provided for many occasions.

The textural changes that nuts undergo after deep fat frying are almost as important as the flavor changes. The raw nuts are soft and pliable to an extent and may be termed "soggy." In contrast the fried nuts are crisp, a quality which is a well-known, desired and enjoyed characteristic, but is poorly defined. It is thought to be largely due to the decrease in moisture during deep fat frying. Thus, the lower the moisture the more crisp the nut becomes.

Another term, perhaps more expressive than absorption or pickup, would be inter-fat transfer or exchange, for the evidence supports the view that fat transfer between nut fat and frying fat occurs.

All nuts appear to pick up about five per cent of the frying medium. This is based on the frying fat lost relative to the weight of nuts fried. Pecans have a greater fat transfer or pickup of frying fat than this (10-15%). Why fat absorption should be larger for pecans, yet fairly constant for the other nuts, serves to illustrate the need for continuing the research effort in this area. Presumably the cellular structure of pecans accounts for these differences. It is known that nuts will absorb not only water vapor, but certain oily constituents other than frying fats to different extents and rates so that it is wholly believable that cellular constituents and structures vary between nuts.

Evidence for fat transfer may be shown by a simple experiment. Freshly refined coconut oil, cottonseed oil, or peanut oil do not foam when used separately as frying mediums. But if either of the latter two oils are added to the former, in ratios of 10 to 90%, then foaming will occur upon deep fat frying.

Nut oils are similar in chemical composition to peanut oil and cottonseed oil, so it appears that when these constituents are added to coconut oil, the interaction of the fatty acids during frying causes foaming.

The high temperatures attained in frying are apparently sufficient to reduce both density and viscosity of the nut oil to such an extent that it is brought to the surface of the nut and is washed off, so to speak, into the frying medium. This nut oil is then diluted and mixed with the frying medium in a way resembling the mixing of the fresh peanut oil with the fresh coconut oil. This explains the dilution of the frying oil with the nut oil. The absorption or pickup of the frying medium is evidenced by comparatively simple weight experiments in which all weights of oils lost and gained are carefully recorded. For some frying mediums, fresh fat is absorbed to a greater extent than used fat.

Changes Occuring in Heated Fats

It has been generally recognized that three types of degradative changes can occur in an oil. These are: (a) autoxidative oxidation which occurs at temperatures up to 212° F.; (b) thermal polymerization which occurs in the absence of oxygen, between 390°-500° F., and (c) thermal oxidation which occurs in the presence of air at about 212° F. (Perkins 1960).

Autoxidation.—Investigations have shown that in corn, cottonseed and other oils the essential fatty acids, carotene, vitamin A, and biotin, are destroyed during autoxidation. When fed to animals in high percentages autoxidized (rancid) oils are toxic, producing diarrhea, loss of weight and even death. Riboflavin exerts some protective effect when rancid fat is consumed.

The chemistry of autoxidation of ethyl linoleate with oxygen leads to the formation of conjugated ethyl linolate hydroperoxides which can in turn cyclize and form higher perioxidic polymers or combine in other ways to form non-cyclic branched chain products. Such peroxides may also decompose by addition of a carbon carbon double bond with the formation of other hydroxyl and epoxy compounds. Hydroperoxides may, if formed during the course of autoxidation, decompose to ketones, hydroxy epoxy, and keto hydroxy products. If unsaturated peroxides are present, both saturated and unsaturated aldehydic and ketonic products may arise.

Thermal Polymerization.—Oils subjected to heat 6 to 24 hours while frying nuts, potato chips and doughnuts become viscous and ropy due to polymerization. There may be slight decrease in caloric availability, but no significant changes in iodine value, melting point, settling point, fatty acids composition, free fatty acid content, isomerized acids content and solids content index.

In extreme cases such oils may be toxic, especially when taken in larger quantities than usually occurs when eating fat fried nuts.

The chemical changes taking place are primarily those of a normal Diels-Alder reaction. Polyunsaturated acids such as linoleic, linolenic and eleostearic acids undergo thermal polymerization after conjugation to form polymeric products. Thermal polymerization of an unsaturated oil results in the formation of cyclic monomers, diners, trimers and even higher polymers. Several other compounds are formed in small amounts as a result of the interaction of shorter chain compounds with normal fatty acids.

Thermal Oxidation.—The chemistry of oils oxidized at high temperatures is more complex than that of thermal or oxidative polymerization since both heat and oxygen are involved. During thermal oxidation unsaturation decreases, conjugation decreases, and nonconjugated acids increase. As the polymer content increases the Rast Molecular weight also increases while the iodine values decrease. Cyclic compounds do not form and Dills-Alder reactions occur only slightly. Thermal oxidation in some oils produce various types of polmeric materials of higher molecular weight and high oxygen content.

All of the above three types of reactions vary with the kind of frying oil used, the temperature, the amount of exposure of air and the length of time it is used.

Fat Fryer Design

Today we have available large continuous fryers capable of frying 15,000 lb., or more, of nuts in a single shift. These machines are completely automatic and need only be set for each type of nut.

Batch deep fat fryers may be small, such as the two-pound capacity unit, or large, such as the 800-lb. capacity units. These are semi-automatic for an operator must direct the nuts into the baskets and must remove the nuts from the fat when frying is complete. The nuts are then cooled on a stationary table or continuous belt with air passing through the nuts.

One of the most important characteristics of a deep fat fryer, batch or continuous, is the ratio of nuts to fat. Its importance stems from its effect on the condition of the frying medium. This ratio refers to the number of pounds of nuts in the fryer at any time and not to the total pounds of nuts fried per shift.

An example may illustrate the point. If the amount of fat in a fryer is relatively large and the pounds of nuts relatively small, the turnover of frying fat in the deep fat fryer will be small. Suppose we had a continuous fryer which holds 1,600 lb. of fat. Secondly, suppose 15,000 lb. of peanuts are to be fried on one shift. Assume the nuts absorb five per cent of the frying fat and that this is replaced with fresh fat periodically throughout the frying of these nuts. Thus, after the first day's frying, 800 lb. of the original fat has been absorbed, 800 lb. remains and 800 lb. of fresh fat has been added back. If we continue these assumptions for five days, we find that after this time 6¼%, or about 100 lb., of the original fat remains; 12½% of the fat added on the second day remains; etc. Thus, turnover of the frying fat is slow if the ratio of nuts to fat is small.

Even if these same assumptions were maintained except for reducing the amount of frying fat to 1,000 lb. from 1,600 lb., the situation, though improved, is not completely desirable, for on the third day there is still 7.5% of the original fat in the fryer.

In the batch fryers this ratio can very nearly approach "1," that is there can be about the same number of pounds of nuts as number of pounds of fat. This usually means that the turnover of frying fat is greater in a batch fryer and less heat degradation will take place. Equilibrium will be earlier attained and the equilibrium point will be lower, in properly designed batch fryers.

An equally important consideration is the method of heating the fat. The flame tube method is quite commonly used. However, equally satisfactory results should be attained by either remote heating such as with heat exchangers or by heating the fryer from underneath. The only difficulty that we might note that arises with flame tube heating or remote heating of the fats is the extra volume of fat that is required for the tubes or exchanger.

This seems to be an inherent disadvantage of a continuous deep fat fryer, that is, its rather large requirement of frying fat. Ideally a continuous nut fryer should incorporate a minimum amount of fat relative to the pounds of nuts in the fryer at any one time.

The continuous deep fat fryer, unlike the batch fryer, maintains relatively constant temperatures throughout the period of frying. These temperatures must be maintained between 275° F. and 335° F. depending on the nuts to be fried. The B.t.u. requirements to heat the fat to these temperatures and to maintain these temperatures while nuts are continuously conveyed through the fat are sizeable. It is not surprising that some chemical changes take place in the fat due to the intensity of the heat and the length of time the fat is subjected to it.

The advantages of the continuous fryer over the batch fryer are the number of pounds that can be processed, subjecting the nuts to a more uniform and consistent process, a completely automatic operation, to name a few.

Some further considerations that must be taken into account in deep fat fryers are the conveying systems, continuous filtration and circulation of the frying fats, exhausting the steam volatiles, and accessibility and ease of cleaning of all parts of the machine, to mention some of the more important.

The primary concern of the continuous fryer is to convey nuts rapidly through the hot fat. The conveyor must be designed to carry the load at variable speeds, for different nuts require different lengths of time in the fat. The load, that is the number of pounds of nuts on the belt at any one time, is generally quite small. Pecans and filberts may float on the frying fat and, therefore, devices to keep them immersed in the frying oil may have to be installed on continuous fryers.

A fryer should be equipped to continuously filter and circulate the frying fat. Filtration will remove some of the polymers and, of course, it does remove fines and other debris from the fats.

An efficient exhaust system is especially important for a continuous fryer because removal of the volatiles with the steam is important in order that these are not returned to the fat.

The fryer should be constructed of materials that are easily cleanable and will not induce rancidity or oxidative problems. All parts of it should be easily accessible and in the case of a continuous fryer, the conveyor should be easily removable. It appears that this fact is largely true; but, since nuts are complex and little is known about the changes that take place in them during deep fat frying, other reactions—such as protein denaturation or oil expansion to disrupt the cellular structure—may occur and contribute to the crisp quality in some unknown way.

The color or appearance of either shelled or blanched nuts changes noticeably during the deep fat frying process. Blanched nuts develop a light golden brown color upon deep fat frying. Shelled nuts, those with the skins, develop a considerably darker skin color upon deep fat frying. The raw almond skin is a light red, whereas after deep fat frying, the color becomes deeper reddish brown. This change is apparently due to a heat induced reaction affecting the tannins natural to the skin.

Salt is generally added to deep fat fried nuts after cooling to enhance further the flavor characteristics of the nuts. The addition of salt in a manner so that it will adhere to the surface of the nut is difficult to accomplish on a dry roasted peanut. Salt is easily added and it adheres to a deep fat fried nut, especially well if a small amount of dressing oil is added. The granulation of the salt also affects the adherence to the deep fat fried nut, the rule being: the finer the salt the better the adherence.

Another point to consider is the small losses or gains of weight observed after deep fat frying. In contrast, when the nuts are dry roasted, considerable losses in weight from the raw product are encountered.

The situation is actually more complex, for weight losses or gains depend on at least four factors: first, the kind of frying fat; second, condition and type of nut; third, length of time the nuts are immersed in the fat; and fourth, the temperature of the frying fat.

The gain or loss in weight of the nut after frying, is directly related to the absorption of frying fat by the nut. This also depends on the same four factors: fat, nuts, time, and temperature. An example of this dependence is that both peanut oil and cottonseed oil are absorbed or picked up by nuts to a greater extent than coconut oil when these fats are used as frying mediums. Likewise at high temperatures of frying, comparing results from studies at 350° F. to those at 275° F., less frying fat will be picked up at 350° F.

There are some indications that the flavor of the deep fat fried nut is preferred to the dry roasted nut. This observation has not been noted with pecans, but is of special interest with cashews where the milk sweetness may be masked by dry roasting.

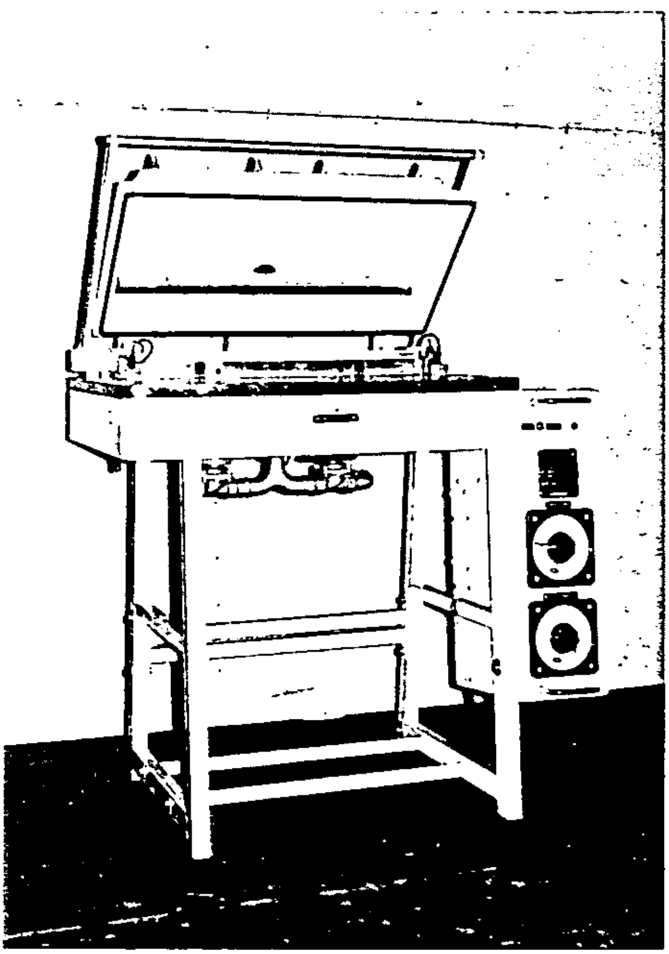
Thus, deep fat frying alters and improves the flavor, texture, appearance of nuts and is economically sound. Deep fat frying of nuts makes them much more pleasantly edible than they are in the raw state.

Nut Changes After Frying

Changes that take place in nuts after being deep fat fried include both long term and short term flavor alterations. The major flavor development of decided economic importance to salters is staleness or rancidity. This flavor development makes the nuts unsalable and may lower their nutritional value if they are sufficiently oxidized.

The commonly known factors that affect or induce the development of rancidity and staleness are heat, certain light radiations, oxygen, certain heavy metals such as iron and copper, certain enzymes, and moisture. As mentioned earlier, the latter also affects the texture of nuts.

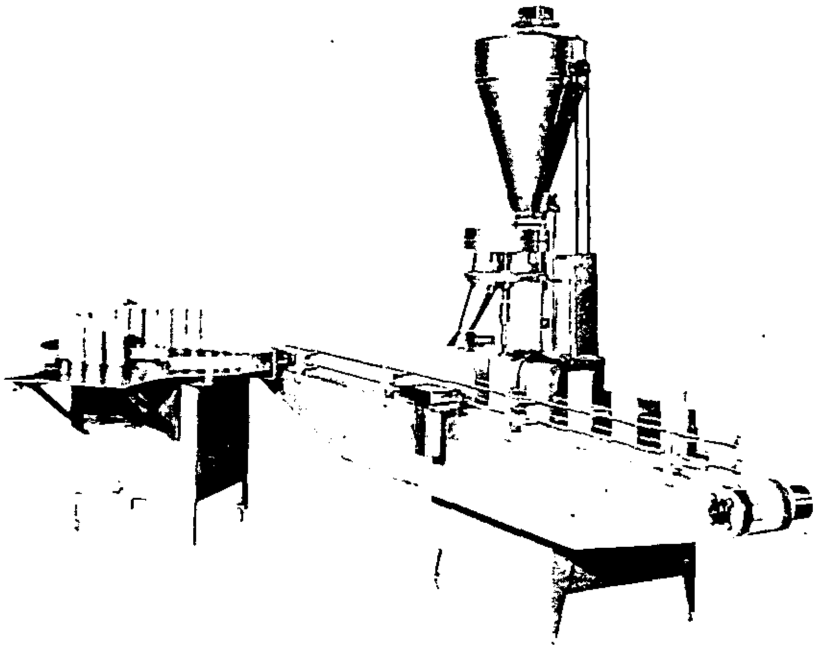
Other factors that affect the off-flavor development of nuts are the kind, type, and condition of frying fat and dressing oil. These factors will be further developed in our discussion of frying mediums.



Courtesy May Industries

FIG. 30. VACUUM SEALER FOR BAGS OF NUTS

The unit requires manual positioning of the filled pouches in the sealing chamber and manual closing of the cover. The vacuum, which is always on, locks the cover in place and evacuates the air from the chamber. At a predetermined point the sealing bar makes contact and the pouch is sealed and held under pressure until the seal has had time to cool. When the cycle is completed air is automatically fed into the chamber and the cover raises slightly. This unit can seal 20 4-inch pouches per minute, with a sealing cycle of 15 seconds.



Courtesy Karstrom Company

FIG. 31. ROTARY CAN UNSCRAMBLER TABLE AND AUTOMATIC NUT FILLER

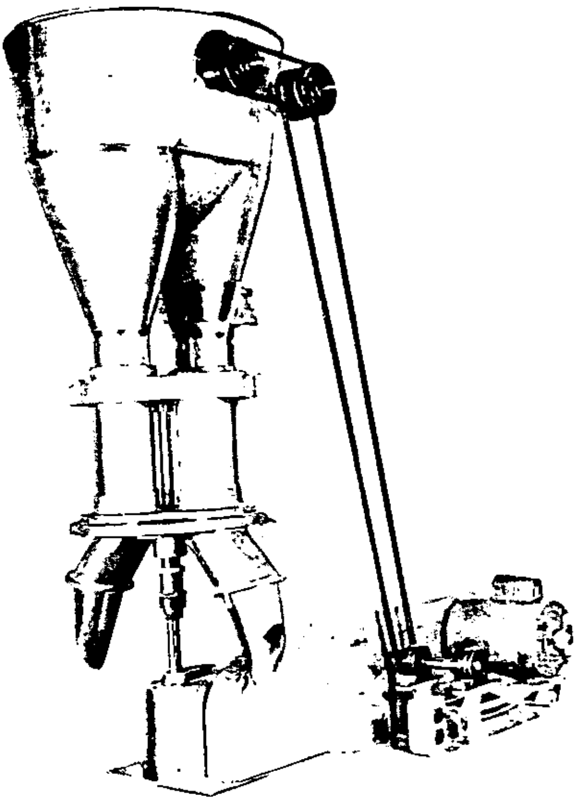
The unit is equipped with a "no container no filler" device which automatically shuts the filler head off when can flow is stopped. Quickly interchangeable parts allow a wide range of products and weights, as well as containers, to be run.

Less direct factors affecting off-flavor development are the handling, packaging, and storage of the nuts after frying until they are consumed.

Nuts are packaged in vacuum cans or flexible plastic films and are merchandised either in these or in bulk in display cases. While the nuts packaged under vacuum are protected excellently, those in the plastic films, though protected very adequately, do have limited shelf life. The nuts merchandised in display cases are subject to the least protection.

The nut which causes the greatest problem insofar as off-flavor development is concerned is the peanut. It has the shortest shelf life of all nuts we fry, with the possible exception of shelled sunflower seeds.

Rapid flavor change does take place within a few days after frying for all nuts. That is to say, the freshly fried nuts may score "9" on the 9-point hedonic scale, but within a relatively short period, a matter of days, that freshly fried flavor is lost and the peanuts may then score only "8" or "7". The scores then stabilize for a period of time where apparently little flavor deterioration takes place. The transition from fresh flavor to rancidity or staleness is progressive and slow, not rapid.



Courtesy Karstrom Company

FIG. 32. DOUBLE DISCHARGE FILLER FOR NUTS AND CANDIES

It can be adjusted to automatically discharge weights of from ½ to 5 lb.

The rapidity with which peanuts may develop staleness, of course, depends upon storage conditions. However, the slow but progressive deterioration just described takes place under room temperature conditions (75° F.) and with nuts packaged in flexible films. The characteristic rancid or stale note will begin to be detected on the surface of the nut or skin at first. Later it will gradually permeate through the entire nut.

Cashews and almonds may be characterized as similar: both take considerably longer to develop a rancid or stale flavor such as in the case with pecans, and in fact many never do. Cashews, however, have a flavor deterioration, presumably an oxidative change also, that is characteristic of this nut. It is difficult to describe the flavor changes that take place in cashews except to note the loss of sweetness, and this generally occurs rapidly. The cashew is still highly acceptable for a long period of time after this, but this delicate sweetness has lessened in intensity.

Courtesy National Equipment Co.

FIG. 33. BAGGING MACHINE FOR NUTMEATS

This is a fully automatic machine using pre-made polyethylene bags. In operation, the hopper of the scale is filled with the product to be bagged. The vibrator accurately fills bucket. When the correct weight is in the bucket, bucket automatically discharges into the polyethylene bag. The next bag is opened, ready for filling while the bucket is being filled. The filled bag can be discharged automatically onto a tying machine or heat sealer.

The cashew, incidentally, of all nuts, is the only one with an appreciable amount of natural sugar—about 5–7%.

Changes in Frying Medium

The third topic will be the changes that take place in a deep fat frying medium and how these affect nuts.

A simple test illustrating these changes may be outlined. In this experiment nuts which have been fried in a fresh medium are compared with those fried in a used medium. The used medium may represent the fat commonly employed as the frying fat in the plant. If taste tests and shelf life studies are designed to compare the nuts fried in these two media, it will be found that the nuts fried in the fresh fat will have a longer shelf life than the nuts fried in the used fat.

Used fat is a frying medium to which freshly refined fat is added periodically to maintain a certain volume and which has achieved by this addition a type of equilibrium. The step-wise approach to this equilibrium may be followed by measuring any number or combination of analytical values such as color, viscosity, free fatty acids, iodine number, etc. to name some of the simplest. Once this quasi-equilibrium is attained, the analytical values chosen to measure it will vary between rather wide limits, depending upon the conditions of frying.

In some cases the quasi-equilibrium will, apparently, never be reached. This is because the frying conditions are such that the analytical values indicate progressive deterioration of the fat to such an extent that replacement of this fat is recommended before equilibrium is effected.

Thus, the used fats have undergone changes, since the nuts fried in the fresh fats are more stable than those fried in the used fats. This decrease is not large, but it is a present and an important consideration for deep fat fryers.

This phenomenon has been observed in all cases investigated. The patterns repeat themselves. Some fats show greater differences than others between the fresh and the used condition. But in all cases, the nuts fried in the fresh fat are more stable than those nuts fried in the used fats.

Another problem that may be encountered with frying mediums is off-flavor development in the nuts, apparently due to some constituent in the frying fat, either natural to the fat or picked up by the fat in improper processing, or perhaps due to something added to the fat inadvertently. In this case, the fat may be re-refined, rebleached, redeodorized, or simply filtered continuously in the plant. In addition to this, when a new or modified frying fat is used, every effort to test the material for possible off flavor development in the nuts in both fresh and used form should be used. This usually involves deep fat drying studies along with long term shelf life and taste panel studies on at least two kinds of nuts under two or three sets of storage conditions. Our criterion of judgment in this particular work is based on what cashews, etc., should taste like under standard conditions.

One most important phenomenon that takes place in deep fat frying is the fat absorbed or picked up by the nut dring frying. It appears to be a physical mechanism and is recognizable by the disappearance of frying fat and the need for replacement. It is also the reason why equilibrium of the frying fat exists. It is apparently the major factor which contributes to the decrease in the shelf life of nuts fried in used fat.

Chemical Compounds Formed.—Chemical compounds formed in fats as a result of three types of degradative changes are autoxidation, thermal polymerization, and thermal oxidation. The compounds formed as a result of thermal oxidation are the most important in deep-fat frying. Experiments to determine the effect of heating, turnover rate, steam, in deep-fat frying on the deterioration of cottonseed oil and tallow showed that the amount of polymeric material increased regularly as heating time increased. Heating, alternated with cooling cycles, increased the deterioration of cottonseed oil. The act of frying a food product or of simple addition of water exerted a strong deteriorative effect on heated cottonseed oil. Highly unsaturated oils form a multiplicity of compounds when they are heated as in deep frying. Twenty compounds, ranging in molecular weight from 446 to 970, have been isolated from thermally oxidized corn oil. One of these has been completely characterized and appears to be a mixture of four positional isomers of a branched long-chain dicarboxylic acid. To simplify problems in working with a highly oxidized mixture containing many components, synthetic triglycerides prepared from palmitic, stearic, and oleic acid were prepared and oxidized. 2-Oleyl-1,3-distearin was oxidized for 24 hours in the presence of air. The major component of the oxidized material was isolated. Results obtained from chemical degradation and infrared and mass spectroscopic examination indicated that this compound was the branched-chain dicarboxylic acid, 10-propyl heptadecandioic acid (Anon. 1966A).

Kettle Composition.—Copper or copper-containing metals are to be avoided in any deep fat frying system, since copper has a highly prooxidant effect on the fat. Even one brass valve in the system, or one bronze pump part can be a source of trouble. Since detergents are constantly used for cleaning, aluminum is not suitable for oil vats, and nickel is too expensive. Stainless steel is by far the most satisfactory.

Effect of Air.—The effect of air on hot fat is perhaps the major factor adversely affecting the deep fat system. Some contact with air cannot be avoided using presently available equipment. Such aeration occurs chiefly on the surface of the kettle fat as heating and frying proceeds, but air is inevitably drawn into the body of the fat owing to currents set up by normal convection or by circulation or agitation. However, excessive aeration due, for example, to cascading or spraying of hot fat anywhere in the system, is unnecessary and must be eliminated. So, also, must the use of pumps in the system which "suck" air, or "churn in" air.

Because the steam given off in the frying process is helpful in purging the frying fat of volatile by-products, adequate exaust of this by-product laden steam from the kettle surface must be provided, and the exhaust system should be baffled so as to prevent flow-back and/or drip-back of the condensate into the bath. Direct draft must be avoided least it cool the kettle fat too much and result in production of finished product quality problems (Robertson 1967).

SALT FOR NUTS

Salt varies in the amount of impurities, the size and shape of particles, solubility, uniformity, caking properties, density, additives and specific usefulness. Since nuts are low in moisture the salt should be highly soluble; should contain five p.p.m. yellow prussiate of soda, to prevent caking; contain 1.0 to 1.5% tricalcium phosphate; and an antioxidant.

Improved fine flake salt[1] incorporates humectant ingredient, polyethylene glycol, which keeps salt free flowing without caking or lumping. Physical properties include a solubility rate of 7.6 seconds, caking resistance for 6–8 months and apparent density of 0.833. Product has 54 million crystals per pound and insolubles of less than 20 parts per million.

A typical analysis for a good nut salt follows.

Composition[1]

Sodium chloride	99.9%
Calcium sulfate	.08%
Calcium chloride	.006%
Total Solids	10 p.p.m.
Ions	
Calcium	.029%
Magnesium	.002%
Sulfate	.056%
Copper, less than	1.5 p.p.m.
Iron, less than	0.2 p.p.m.
Screen analysis (U. S. fine series)	
Total over No. 40	trace
Through No. 40 over No. 50	18%
Through No. 50 over No. 70	48%
Through No. 70 over No. 100	27%
Through No. 100	7%
Moisture	.05%
Density	61 lb. per cubic foot
Solubility	8 seconds when fully dispersed
Additives, tricalcium phosphate	1.0%
Antioxidant	0.%

[1] Hardy Salt Company.

SUGGESTIONS FOR NUT SALTERS

At times nut salters are bothered somewhat because the salt falls off the surface of the salted nuts and into the bottom of the bag or can, principally because of rough handling in shipping. This difficulty is more likely to be encountered where nuts are fried in liquid oils rather than solid shortenings. Where nuts are fried in solid shortening, the salt is applied before the nuts have cooled down to room temperature. At this point the frying fat is still in a melted condition on the surface of the nuts. When the nuts

[1] Diamond Crystal Salt Company.

cool down to room temperature, the shortening on the surface sets up as a solid fat. The salt is thus held firmly to the surface of the nuts and will stay there in spite of considerable handling. This is also true in cases where nuts are fried in coconut oil, since coconut oil sets up at approximately 76° F. Below this temperature coconut oil is a fairly firm fat. Where nuts are fried in cottonseed oil, peanut oil, olive oil, or other oils that are liquid at room temperature, there is very little binding action to hold the salt on the surface of the nuts.

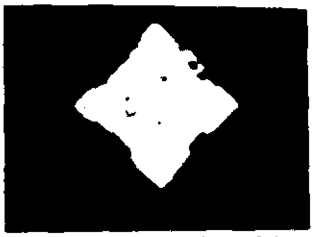
Some nut salters roast the nuts rather than fry them. Consequently, there is no solid fat to help bind the salt on the surface of the nut. In this case, the little binding action observed is caused by the trace of natural nut oil which comes to the surface during the roasting period.

If the salt falls off the nuts and drops to the bottom of the bag, the following suggestion will correct the difficulty. When the warm nuts are removed from the kettle and drained, or where they are removed from the ovens after roasting, they should be spread on table to cool slightly. Then about two pounds of warm coconut oil should be "atomized" on each 100 lb. of nuts. Because the nuts are considerably warmer than the coconut oil, it will be noted that the oil does not seem to penetrate the nuts but remains on the surface. After the coconut oil is uniformly distributed on the nuts by mixing, the salt is added and the nuts are then allowed to cool to room temperature. It will be found that after this treatment the salt will adhere to the nuts very well, thus overcoming the difficulty.

The proper product to use is regular coconut oil which is often referred to as "76° coconut oil." It is not necessary to use plasticized coconut oil since the straightforward product will be entirely satisfactory.

This difficulty is quite likely to be encountered with new crop nuts. For some reason, freshly harvested nuts do not hold the salt as well as nuts that have been cured for a considerable period of time. It may be that the high moisture content is responsible, but this is not definitely known.

Naturally, the type of salt plays an important part in clearing up this difficulty. It is much more difficult to hold fine granulated salt on the surface of the nuts than is the case with a flake salt. The little cubes have much less surface and the binding action requires a high amount of surface. Crystal fine prepared salt is composed practically 100% of flasher flakes. If examined under a magnifying glass, it was noted that these flakes are composed of minute cubes fastened together in odd shapes. There are little crevices and indentations on the surfaces of the tiny flakes that permit the fat on the surface of the nut to "catch hold" on the salt particles, binding the salt firmly to the surface of the nut. It is generally recognized in the trade that when nuts are salted with fine flake salt, because of its instant solubility, uniform granulation and high purity, the lips are not irritated by the salt.



Courtesy Morton Salt Co.

FIG. 34. A GRAIN OF FLAKE SALT THAT ADHERES TO ROASTED NUTS

Nuts are by their very nature rich in oils. It is common knowledge that copper and iron accelerate rancidity of fats and oils and therefore shorten the shelf life. It is essential to use a salt with the minimum amount of copper and iron impurities.

A companion salt product used by many nut salters is Diamond Crystal Fine Prepared Antioxidant or Fine Flake Prepared Antioxidant Salt. The shelf life of salted nuts is increased up to 137% when using 0.02% concentration in the cooking oil and salting with an antioxidant salt as shown in a Georgia Experiment Station test.

Antioxidant salts combine the right salt—the best nut coverage, solubility, grain size and shape—with the right amount of antioxidant ingredients to protect the delicate nut flavor the maximum length of time (Tech. Bull. 10, Diamond Crystal Salt Company).

EDIBLE NUT COATINGS

An edible coating process is reported to add 12 months to the storage life of nutmeats when held at room temperature. The coating "Myvacet" is a patented product containing actylated monoglyceride, butylated hydroxyanisole and butylated hydroxytoluene. It is applied up to five per cent to the nutmeats. The antioxidant level is 100 to 150 p.p.m. The process is applicable to pecans, almonds, filberts, walnuts and other nuts (Shea 1965).

Tapioca dextrin is used as a nut coating. This is a unique low viscosity extremely clean, starch product with an unusually bland flavor. The crystal gum is a white powder with about seven per cent moisture and a pH of about four. It is easily dispersed in cold water but requires heating to achieve optimum solubility and application characteristics. The gum has little or no tendency to foam during heating or "shrink" on cooling. (National Starch and Chemical Co. 1966)

Make coating solution by blending first four ingredients at 190° F., and allowing to cool. Add the nutmeats and "pan coat" in revolving kettle at about 290° F. for 1½ to 3 minutes.

Formula

Crystal gum	3.5 oz.
Monsodium glutamate	.5 oz.
Water	6.5 oz.
Antioxidant	.2 oz.
Nutmeats	10 lb.

Zein is another nut coating. For nut coating zein provides an oil barrier, acelytated monoglycerides provides a moisture barrier and a combination antioxidant (butylated hydroxanisole, nordihydroguaiaretic acid and citric acid) extends the shelf life of the product.

Nutmeats (pecans, black walnuts, English walnuts and others) treated with about one per cent of the antioxidant (in alcohol solution) extends the shelf life up to four times (Cosler 1958).

SYNTHETIC NUTS

Synthetic nuts that simulate particular varieties of nutmeats can be made under a patented new process. A film-former, such as dried egg albumen, and a filler, such as dried ground wheat germ, are blended with an oil, such as cottonseed oil to form a smooth slurry. This is then agitated at high speed, during which sufficient water is added to hydrate the film-former. After all the water has been introduced the high speed is continued until a viscous dispersion results.

At this point, the product is a continuous hydrated film throughout which the oil component is dispersed. The jelly-like dispersion is then extruded into sheets, molds or other forming devices and dried. Since the moisture is in the cellular film portion and is partially insulated by fat globules, drying is slow.

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TREE NUTS Production Processing Products

Volume Two

Pecans — Pine Nuts — Pistachio Nuts
Black Walnuts — English Walnuts

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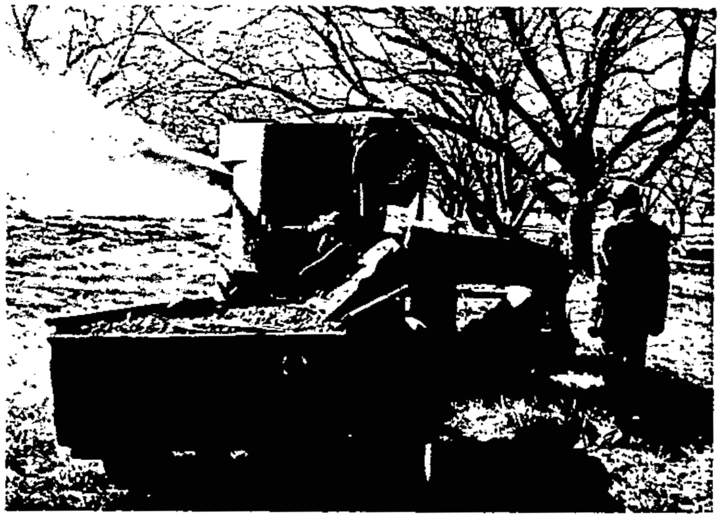
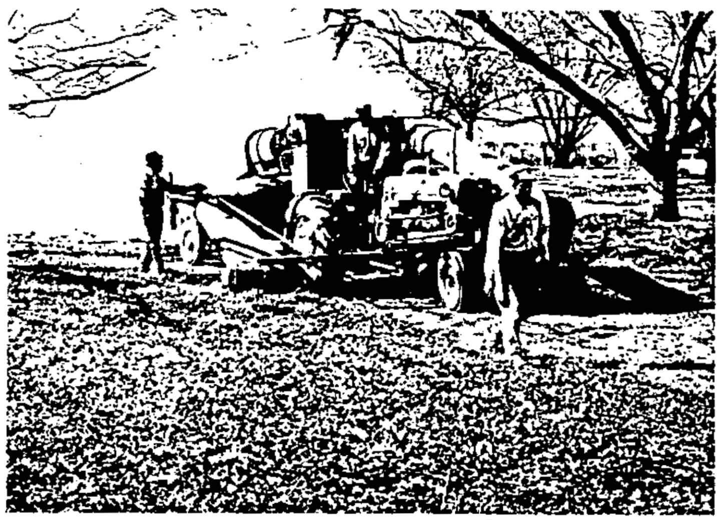


Courtesy Phelps Fan Mfg. Co.

FIG. 88. PECAN HARVESTER

After being shaken from the trees the nuts (and leaves) are sucked from the ground. The trash is separated and the pecans are collected in the trailer.



Courtesy Phelps Fan Mfg. Co.

FIG. 89. FRONT VIEW OF NUT VACUUM-TYPE HARVESTER IN PECAN ORCHARD

Three men are required to operate it continuously—one to drive tractor, one to keep the harvester, and another to go ahead and remove large rocks and sticks.

sand, the harvester works best. In orchards where the land is cultivated ground conditions are not likely to be favorable for air vacuum harvesting. Often small clods are created which enter the machine's air stream and collect with the pecans. Also, cultivated sandy soil without grass allow the equipment to pick up dirt.

Dry weather is an important necessity for mechanical harvesting. The harvester will not function properly in wet weather. Cattle must be removed well before harvesting in order to give manure time to cake and dry.

During the first year of suction harvesting in an orchard, there is likely to be a considerable amount of "old wood" picked up with the pecans. There should be less of this in subsequent years.

While the land does not need to be flat, land smoothing is necessary. The smoothing operation consists of discing once, spike tooth harrowing and finally dragging the land, prior to planting grass. Irrigated land is suitable for mechanical harvesting pecans.

Much experimental work is under way, both by state and federal experiment stations and by industry, to improve mechanical nut harvesters. They are still too expensive for small orchardists. There is need for a fairly light, compact, harvester that picks up the nuts, with some trash, and loads them on light trucks, that carry them to a nearby station for cleaning and grading the nuts.

FARM CLEANING PECANS

Small lots of farmers stock pecans are picked up by hand and graded at the same time. In this case, removal of pops and shrivels and sizing is done at the collecting point. Many farmers harvest from 1,000 to 50,000 lb. of pecans by machine which should be cleaned and graded immediately. A typical operation where a mechanical harvester is used is to have the nuts come to processing equipment in bulk. The nuts may be processed directly from the harvester trailer or they may be held temporarily in holding bins.

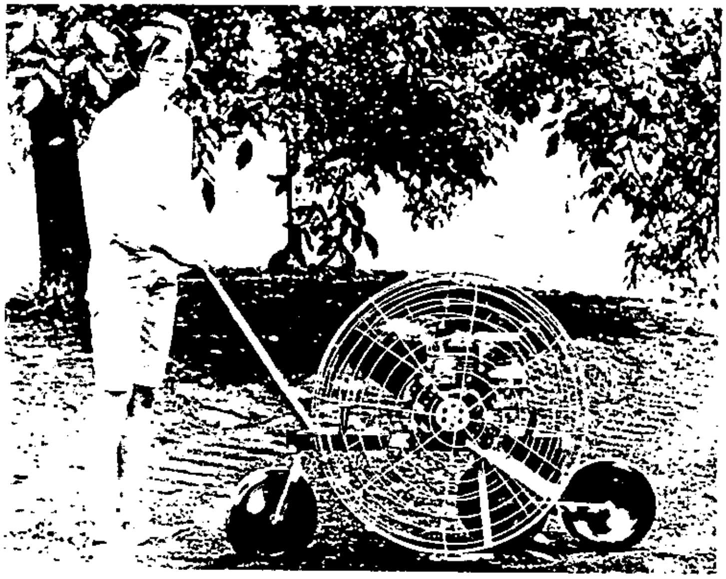
In either case, a flight type elevator might be used. It should provide at least ¾ in. clearance between the end of the cleat and the side of the elevator trough to prevent crushing of the nuts. Most bucket type or augers are not satisfactory for nuts.

Stick Remover

The first cleaning operation is to remove the sticks with a "rodding" machine. This is a cylindrical cage with spaced rods for the outside and placed in a horizontal position. One end is slightly higher than the other. As the cage rotates, sticks are picked up by finger bars and dropped on a separate outlet from the pecans. Dirt and most leaves also fall through the rods.

Pop and Shrivel Remover

The nuts go from the rodding machine onto an open chain link belt, and pass under an air vacuum nozzle, when the light nuts (pops) and any re-



Courtesy (Davebilt) Clarance Davidson Co.

FIG. 90. "BLOWER" TO PILE PECAN (OR ALMOND, FILBERT, WALNUT) LEAVES SO THAT NUTS CAN BE GATHERED BY "PICKER" SHOWN BELOW

Courtesy (Davebilt) Clarance Davidson Co.

FIG. 91. "PICKER" FOR HARVESTING NUTS FROM THE GROUND FOLLOWING REMOVAL OF LEAVES BY "BLOWER" SHOWN ABOVE

maining leaves are removed. Vacuum is controlled by adjusting the height of the nozzle above the belt. Adjustments of the nozzle may be necessary when the variety of nuts being processed is changed.

A second vacuum nozzle may be used just past the first to remove the shrivels which have limited commercial value. Both vacuums may be operated from the same fan but separate collection for material removed must be provided.

Grading Table

Unhulled and broken nuts need to be removed prior to sizing. This is a hand operation performed by passing the nuts over a second flexible steel belt in front of the workers.

Sizing Machine

Nuts should now be sized. Some equipment will separate the nuts into three sizes—small, medium, and large. Larger equipment will separate the nuts in up to six sizes usually from 10/16 in. to 15/16 in. in 1/16 in. increments. However, no equipment is available for separation according to variety.

POST-HARVEST CHANGES IN PECANS

The first changes that occur in pecans after harvest result in improvement of quality by curing; later changes result in degrading the quality by staling, discoloration and rancidification. Post-harvest changes include: (1) decrease of moisture in the kernel volume about ten per cent; (2) increase in peroxide values from 0 to 1.5 millimols of oxygen per kg. of oil, increase in free fatty acid values from 0 to 0.5% as oleic acid; (3) oxidation of tannins in the seed coat, causing a change in color from pale to medium tan; and (4) development of characteristics of pecan appearance, aroma, flavor and texture, resulting in optimum eating qualities.

Changes during curing differ among varieties and at different temperatures and moisture levels, most of which enhance the marketability and eating qualities. However, when allowed to continue at room temperature for more than about three weeks, at 100° F. for more than one week, or at 50° F. for more than three months there is a gradual development of staleness and rancidity in the nuts (Woodroof and Heaton 1961).

Optimum flavor develops in pecans when held under farmhouse conditions for about three weeks after harvest. After this time, storage at 40° F. or lower with 70% to 80% R. H. is necessary to hold the fresh color, aroma and flavor to more than three months.

Freshly harvested pecans are sensitive to moisture. The first evidence of this is in the orchard where pecans are subject to weathering, infection with mold, splitting and occasional sprouting. Pecans gathered as they fall from the trees are practically free of molds; whereas those which remain on the damp ground for a week or more, are high in moisture and usually contain a high percentage of discolored and moldy kernels.

Experiments showed a direct relation between the time pecans laid on wet soil, the moisture content and molding of the kernels. Molding increased from 2 to 26% due to lying on the ground 3 days where a small amount of chicken manure had been spread, and for from 44 to 66% due to 6 days exposure. Thus nuts that fall on the ground in pastures are more likely to mold than those which fall on practically sterile soil (Woodroof and Heaton 1958).

Furthermore, pecans which lie on wet soil for an extended period or until they become fully wet, turn amber color slowly while in the shell and discolor, immediately after shelling. This is due to absorption of soluble tannins from the hulls, or packing tissue of the shells, by the kernels. This discoloration is retarded by refrigeration but is resumed upon removal from refrigeration. When shelled and exposed to air at room temperature, the meats darken within a few minutes. Discoloration due to weathering affects the appearance and grade of the meats more than the flavor. Unless such nuts are dried promptly they mold or develop bitter pit. Schley and other thin shell varieties are especially subject to post-harvest discoloration, if allowed to weather before storage.

On the other hand, pecans which were harvested without weathering or "moisture pick-up" neither discolored or molded while in common storage through the winter, or at 0° F. for more than five years. There was also no change in color upon removal from 34° or 0° F. storage for shelling. These nuts had a bright tan color, crunchy texture, and very desirable flavor.

DRYING PECANS

Pecans need to be dried to a kernel moisture level of about 4.5% as soon as practical after harvesting. This is to prevent molding, discoloration, and breakdown of the oil. Drying is necessary also to properly shrink the kernels and prevent "stick-tight" shells during subsequent shelling (see Figs. 93 and 94). Controlling moisture is the most important factor in harvesting, storing or processing pecans, even for as short a time as one week.

Moisture Is High When Pecans Are Harvested.

The first problem of harvesting is removal of sap moisture from the nuts to prevent molding, and discoloration. Under fair weather conditions this moisture in the pecan kernel drops gradually from about 30 to 8% as the nuts mature on the trees and normally dehisce. Drying is accelerated as the nuts lay on dry soil or leaves, or are held for 2 to 4 weeks in dry storage. Under these conditions moisture content of the meats equalize at about 4½% and that of the entire nuts at about 8.5 to 9.0%. It is also under these conditions that optimum color and maximum flavor develop.

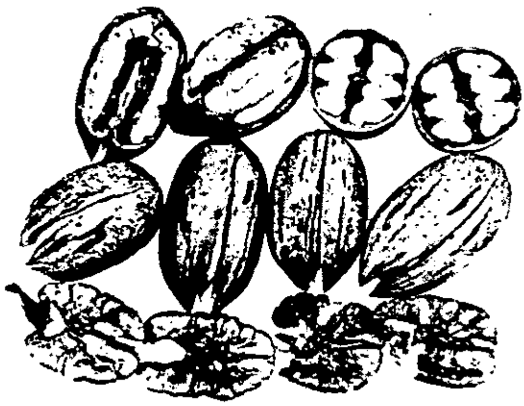
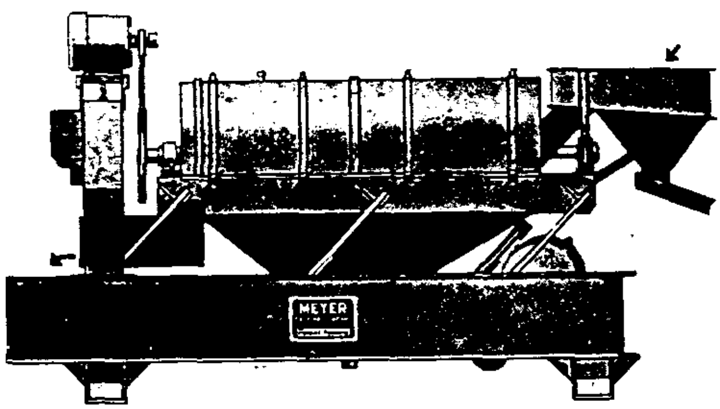


FIG. 92. PECANS THAT GERMINATED (SPLIT) WHILE ON THE TREE DURING WET WEATHER

They usually molded at the apex.



Courtesy Meyer Machine Co.

FIG. 93. CONTINUOUS NUTMEAT MOISTURE EXTRACTOR
The unit is four feet high and about eight feet long. Wet nuts enter on left and are discharged at right, with moisture drain at the bottom. It is a production line unit that dries nutmeats in minutes.

Removal of sap moisture is first from the outershell, followed in order by removal from the inner shell, the middle partition and finally the kernel. Tests have shown that the most satisfactory color, texture, stability and flavor, results when pecans are dried "naturally"; that is, by constant movement of dry air around the nuts for at least three days. Artificial or rapid drying methods with heat should not be used for normal drying of pecans, which have not been rewet.

Should removal of sap moisture be interrupted by prolonged rain while the nuts are on the trees, molding, rotting or sprouting may occur. Splitting of shells or sprouting on the trees results in rupturing the seed coats and discoloration of the kernels, and if allowed to continue for a week or more, will destroy the sale value of the nuts.

Schley and other thin shell varieties are especially subject to cracking or sprouting on the trees. They are also the varieties that do not dehisce readily. When prolonged rain occurs during the ripening period, these should be harvested quickly and dried as rapidly as practical.

Pecans Are Injured if Rewet

Rewetting, after the sap moisture has been reduced to about five per cent, is probably the cause of more discoloration, molding, rotting, souring and otherwise degrading of pecans than of all other conditions combined. This may occur from rain, prolonged high humidity air before harvesting, lying on wet soil, or from storing in air more than 70% R. H.

Rewetting interupts the normal drying process. The outer shell is the first to be rewet and this becomes darker. The inner shell is the next layer to become brown due to solubility of tannins. The tannins stain the seed coat and kernels and impart a bitter flavor.

To prevent the growth of microorganisms rewet pecans must be dried or refrigerated within a week. Rapidly circulated low moisture air, at room

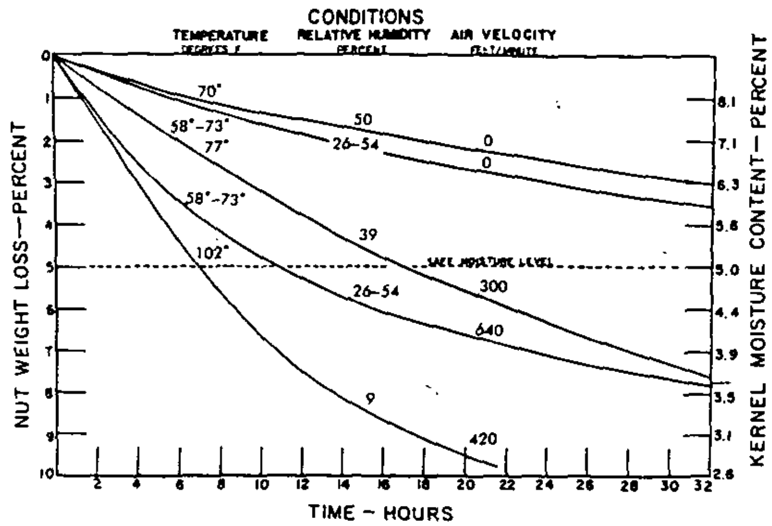


FIG. 94. THE RELATION OF LOSS IN WEIGHT OF UNSHELLED PECANS, AND CHANGE IN MOISTURE CONTENT OF THE KERNELS, TO TIME OF DRYING, AT VARIOUS CONDITIONS OF TEMPERATURE, RELATIVE HUMIDITY AND AIR VELOCITY

temperature, is recommended for drying the surface and outer shell of rewet pecans. The moisture from the kernels then migrates to the surface and evaporates. A safe moisture equilibrium is thereby attained after about 24 hours. To accomplish this the nuts should be placed on racks at a depth of not more than two inches and dried. The air should be warmed, recirculated and dried, or partially replaced with outside air.

Drying in rapidly circulated, low moisture air at refrigerated temperatures is also recommended. This is what occurs in a refrigerated warehouse when air of 65% R.H., or lower, is circulated by unit coolers. The pecans are improved by lowering the moisture content. The quality is retained by lowering the temperature. Drying with refrigerated air is advantageous also in that the color and flavor are better maintained than when heated air is used.

Moisture in Pecans Equalizes During Storage

Moisture in pecans stored at 73° F. and 55% R.H. for four months, may increase or decrease, depending upon the moisture content when stored. Results showed that: (a) very dry pecans (7.9% whole nut, and 3.6% kernel moisture) gained in total moisture. This increase occurred in the shell while the meats remained unchanged. (b) In normally dry pecans (8.7% whole nut and 4.4% kernel moisture) there was a shift in moisture from the meats to the shells, without a change in total moisture. Most of this moisture transfer was from meats to the inner shells. (c) In slightly wet pecans (9.7% whole nut and 5.5% kernel moisture) there was a decrease in total and kernel moisture. (d) Wet pecans (12.2% whole nut and 7.9% kernel moisture) decreased in moisture in the whole nuts, kernels and shells.

It was found that in normally dry pecans, 22 to 25% of the total moisture was in the kernels, 27 to 30% was in the inner shells, and 44 to 51% in the outer shells. Since pecans are, on the average, 40 to 50% kernels, and 50 to 55% shells, and since 75 to 78% of moisture is found in the shells, gains or losses in weight during drying or storage would be greater in the shells. These data are summarized in Table 72.

TABLE 72

MOISTURE IN REGIONS OF PECANS

Region	Very Fresh Pecans %	Fully Dried Pecans %	Rewet Pecans %
Outer shell	20.9	11.3	15–16
Inner shell	50.5	17.9	20–24
Meats	24.3	3.8	8–12
Middle partition	...	...	20–24

Changes in moisture during drying and storage were similar for most varieties, i.e., all lost moisture and weight, and decreased in percentage of total moisture in the kernels. They increased in shelling percent and percentage of total moisture in the shells. During drying six samples of Schley, the kernel content increased from 50.9 to 51.5%; the kernel and whole nut moisture decreased from 4.9 to 4.1% and from 9.0 to 8.3%, respectively; and the percentage of the whole nut moisture found in the shells increased from 72.2 to 74.6%.

TABLE 73

DISTRIBUTION OF MOISTURE IN THREE AREAS OF VERY DRY, NORMALLY DRY, SLIGHTLY WET PECANS, AND WET PECANS, BEFORE AND AFTER STORAGE AT 73°F., WITH 55% R.H.

Parts of Nuts	Moisture Content %		Proportion of Total Moisture %	
	Initial	Stored	Initial	Stored
	Very Dry			
Whole nut	7.86	8.36		
Meats	3.63	3.61	22	21
Inner shell	15.17	16.76	27	28
Outer shell	10.83	11.18	51	51
	Normally Dry			
Whole nut	8.72	8.69		
Meats	4.36	4.19	23	22
Inner shell	15.74	16.81	28	30
Outer shell	10.97	11.04	49	48
	Slightly Wet			
Whole nut	9.69	9.19		
Meats	5.48	4.50	24	22
Inner shell	17.17	17.26	27	29
Outer shell	12.00	11.52	49	49
	Wet			
Whole nut	12.24	9.39		
Meats	7.87	4.55	25	22
Inner shell	20.53	17.35	30	28
Outer shell	14.26	11.85	45	50

Source: Heaton and Woodroof (1965).

When 20 samples of mixed varieties were dried in storage, the kernel content increased from 45.7 to 46.0%, the moisture content of the meats fell from 4.3 to 3.9%; the whole nut moisture remained unchanged; and the percentage of whole nut moisture in the shells rose from 77.1 to 78.9%.

TABLE 74

DISTRIBUTION OF MOISTURE IN THREE AREAS OF THREE LOTS OF PECANS BEFORE AND AFTER STORAGE AT 73°F., WITH 55% R.H.

Parts of Nuts	Proportion of Total Nut %		Moisture Content %		Proportion of Total Moisture %	
	Initial	Stored	Initial	Stored	Initial	Stored
			Schley			
Whole nut			8.99	8.25		
Outer shell	36.4	36.2	11.83	11.26	47.9	49.3
Inner shell	12.8	12.5	17.11	16.70	24.3	25.3
Meats	50.9	51.4	4.92	4.06	27.8	25.3
			Mixed			
Whole nut			8.52	8.59		
Outer shell	40.5	39.7	10.42	11.21	51.8	51.9
Inner shell	13.9	14.2	15.39	16.42	25.2	27.1
Meats	45.7	46.0	4.28	3.92	22.9	21.0
			Stuart			
Whole nut			9.26	9.20		
Outer shell	39.4	38.7	11.30	11.26	48.0	47.4
Inner shell	16.1	16.7	16.94	17.47	29.5	31.6
Meats	43.3	44.6	4.80	4.33	22.5	21.0

Source: Heaton and Woodroof (1965).

High Moisture Nuts May Lose Weight and Shrink in Volume

Several case histories from warehouses have shown considerable losses in weight to be sustained during the storage of nuts. The cause of this was determined from moisture analysis of component parts of the nuts. Data showed that pecans, fresh from the orchard, might contain as high as 24.3% moisture in the meats, 20.9% in the outer shell, and 50.5% in the inner shell; corresponding figures for these nuts after being fully cured and dried were 3.8, 11.3 and 17.9%, respectively. It was found that during the adjustment of moisture in the shells after being stored, a loss in weight resulted in about as much as 10–15%, depending on the condition of the nuts when they were stored.

It was further found that in-shell pecans in storage may lose in volume as well as weight. There may be shrinkage in the length and diameter of the nuts that would cause slack pack.

Moisture determinations of 70 lots of pecans received at two refrigerated warehouses for storage showed that 38 of the lots were above optimum moisture and would be expected to lose weight while in storage; 13 of these were sufficiently high in moisture to produce molding upon removal from storage unless the moisture was reduced while in storage.

During storage, unshelled pecans in 85.3% of the warehouse samples shrunk in length, diameter, and volume, and 73.5% lost moisture from the meats. An example of shrinkage during storage is illustrated by one lot of pecans which weighed 32,488 lb. when stored, and 31,132 lb. when removed from storage six months later. This was a reduction in weight of 1,356 lb. or 3.5%, which should have occurred before storage.

It is important that warehousemen and clients understand that high moisture nuts will lose weight when stored properly, and in this way the quality of the nuts is superior to that when the nuts are dried by the use of heat outside of storage.

TABLE 75

THE INFLUENCE OF MOISTURE ON THE FREE OLEIC ACID OF 320 SAMPLES PECAN KERNELS

Moisture	Free Oleic Acid
%	%
2.0-2.9	0.34
3.0-3.9	0.40
4.0-4.9	0.42
5.0-5.9	0.49
6.0-6.9	0.69
7.0-7.9	1.22
8.0-8.9	1.25
9.0-10.9	1.38
11.0-12.9	3.80
13.0-14.9	12.55

Remoistening Pecans for Shelling May Be Injurious

The moisture content of pecan kernels is raised to about 8.0% immediately prior to shelling. This is to reduce breaking of the meats during shelling. Following shelling and grading the meats, the added moisture should be removed as quickly as practical. This may be done by forcing warm, dry air through the meats, held in bins, or on a belt; or by placing the meats in refrigerated rooms and circulating air at 65% R.H., or lower, through them. In either case the moisture should be reduced to 4½% for storage.

The optimum moisture for pecan meats is about 3.5 to 4.0%. Below this point the meats are too brittle for handling without injury and above this point enzymatic and other activities are increased resulting in more rapid staling (Heaton and Woodroof 1965).

PECAN INSPECTION AND GRADES

The Federal Inspection Service originates and is maintained in the various states through the means of a cooperative agreement between the

United States Department of Agriculture and some state agency, usually with the State Department of Agriculture. The cooperative agreement spells out the duties and responsibilities of both cooperating agencies. Federal-State inspection is available to all financially interested parties in practically all commercial producing areas.

Courtesy of Stuckey's Inc.

FIG.95. IN-SHELL PECANS IN FIVE- OR TEN-POUND BAGS ARE POPULAR AT ROADSIDE STOPS
They are also exported in this form.

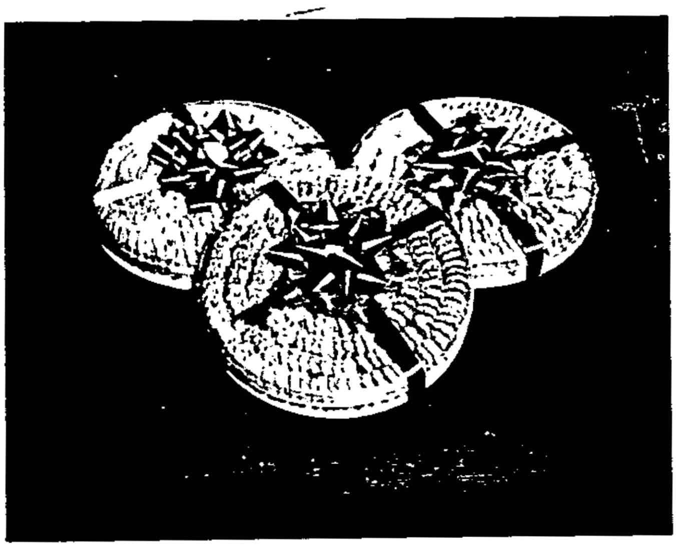


FIG. 96. A FANCY PACK OF PECAN HALVES

Inspection and certification of pecans is invaluable to both growers, buyers and shippers, and in most cases they are willing to pay for the cost of inspection. It cuts down trading risks, can save them time, trouble and money (Scott 1960).

Value of Inspection

Following are reasons for official inspection:

(1) A clear definite interpretation and correct application of the official standards by an Inspection Service is indispensable as the first step in orderly marketing.

(2) An official inspection certificate furnishes a word picture of the commodity and provides a means of long distance dealings between seller and buyer.

(3) An inspection certificate provides a basis for fulfilments of contracts and satisfactory delivery of the product.

(4) The information given on the Inspection Certificate is accepted as prima facii evidence of the facts therein by State and Federal Courts.

(5) The inspector is trained as professionals in that field.

Quality Yark Stick

Standards for Grades of pecans, are shown in the appendix, and are a yard stick for measuring quality.

External qualities for grades of inshell pecans are: finish of shell; color of shells; loose hulls and other foreign matter; shape; staining; and broken and punctured shells.

Internal qualities for grades are: curing; development of kernel; shriveling; leanness and hollowness; external discoloration; internal discoloration; dark kernel spots; reddish or brown dust; brownish or grayish adhering material from shell; decayed; rancid; moldy; or insect injured.

Size

There is no size requirement in either U.S. No. 1 or the U.S. Commercial Grade. However, size is usually specified in connection with the grade as extra large, large or medium. The U.S. Standards provide size designations which may be used in specifying size and which are based upon a combination of count per pound and weight of the ten smallest nuts in a representative 100-nut sample. Size also may be specified in accordance with the maximum number per pound or the range in number per pound without reference to the weight of the smallest nuts. The size may also be specified as an exact number per pound. In addition, size may be described in terms of the smallest nuts or the range in diameters, stated in sixteenths of an inch. See Appendices 5 and 6.

Pecans are covered by U.S. Standards. The two grades for pecans are, the U.S. No. 1 Grade or U.S. Commercial Grade. Both permit certain tolerances for external and internal defects (see Appendix).

The packing or packaging of pecans in accordance with Official Standards is the first step required for orderly marketing and efficient buying and selling. The Standards furnish the yard stick for measuring variations in quality, condition and size; and this use has made possible a basis for satisfactory long distance dealing.

Grades

Inshell pecans are graded as follows:

Size Designation	Number per Lb.	10 Smallest Nuts in 100 Representative Samples, at Least, Oz.
Average	Not more than 52	2.50
Extra large	Not more than 60	2.25
Large	61–73	1.75
Medium	74–90	1.50
Small	91–115	1.25

Shelled pecans have four grades—U.S. No. 1 halves; U.S. Commercial halves; U.S. No. 1 pieces; U.S. Commercial pieces.

Quality factors for graded shelled pecans are: dryness, cleanliness, color, pieces of shell or foreign material, chipped halves, broken kernels and particles of dust, shriveling, leanness and hollowness, discoloration, rancidity, mold, decay or insect injury. In most cases there are specified tolerances, based on weight.

Shelled pecan halves are graded as follows:

	Per Lb.
Mammoth	200–250
Junior Mammoth	251–300
Jumbo	301–350
Extra Large	351–450
Large	451–550
Medium	551–650
Topper	651–750
Large Amber	400 or less
Regular Amber	more than 400

Pecan pieces are graded as follows:

Size Designation	Will Pass Through Round Openings of the Following Diameters In.	Will Not Pass Through Round Openings of the Following Diameters In.
Extra large	...	8/16
Large	8/16	5/16
Medium	5/16	4/16
Small	4/16	3/16
Midget	3/16	2/16
Meal	2/16	1/16
Regular Amber	...	4/16
Small Amber	4/16	2/16

Possibly the most integrated plan for handling pecans was put into operation at Albany, Georgia, in 1966 by the Gold Kist Pecan Co., and Merchants Refrigeration Company. In this operation pecans are mechanically shaken from the trees, windrowed, harvested and separated from the trash in the field by machine, hauled to the warehouse and wind blown to remove pops, graded into seven sizes and run 1500-lb. "tote-boxes," and placed in refrigerated warehouse on the same day without being touched by hand.

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Shelling and Grading Pecans

SHELLING PECANS

Pecan processing began in the early 1920's with the development of mechanical equipment for sizing, separation of faulty nuts, cracking, separation of meats and shells, sizing and grading of meats, drying and packaging. The utilization of pecans was increased by extending the storage life which was made possible by control of temperatures, relative humidities, air circulation, storage atmospheres, and packaging. With these improvements the list of food products containing pecans has steadily increased (Woodroof and Heaton 1961).

Shelling reduces the weight of pecans by about 64%, reduces volume by 50%, and provides seasonal employment in pecan producing areas. At the same time, shelling reduces the storage life of pecans by 75%, by making them more susceptible to insects, mold, staleness, and rancidity. However, the sensitivity of shelled pecans to deterioration has been more than overcome by improvements in packaging and storage methods.

Shelling and grading are steps that tie pecan producers to the end-users. Much progress has been made in the technical and mechanical phases of these two operations since 1950, and much more is expected. Advances result in improved quality, extended markets and a more steady supply.

The shelling of pecans has progressed far beyond the hammer and flat iron stage which existed before 1900. Lacking commercial shelling equipment most pecans were then sold whole and shelled in the home. This resulted in the development of a wide variety of "parlor nut crackers" as shown in Figs. 98 and 99. Many principles of applying the pressure were utilized in the crackers. Some used gentle pressure on the sides or ends of the nuts, others used a stroke on the tip or on the "shoulder" of the nut. They were made of wood, metal or a combination. Most of them resulted in crushing the meat along with the shells, and most of them were adjustable to use nuts of different sizes.

The first successful, automatic pecan cracker was designed by Lee J. Meyer of San Antonio, Texas, in 1918. It revolutionized the pecan industry and became the standard item in the nut processing business. The immediate advantage was the production of a higher volume of halves, as distinct from broken bits and pieces.

Included in a pecan shelling production line today are "tote boxes," elevators, separators, sizing and grading units, dryers, coolers, hoppers

FIG. 97. STEPS IN PREPARATION OF PECAN MEATS FOR STORING AT HOME

Select sound pecans of any variety; moisten beneath wet towel overnight; crack lengthwise without crushing, separate shells and whole halves; dry, pack in moistureproof containers, and store under refrigeration.

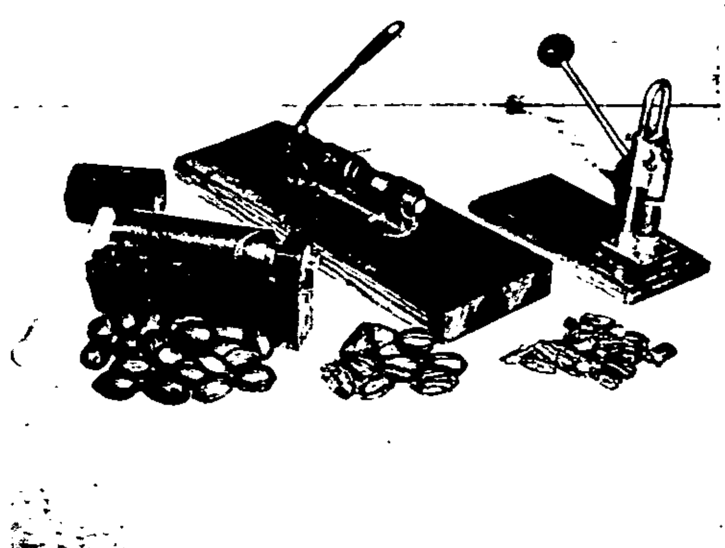


FIG. 98. THREE COMMON TYPES OF HOME PECAN NUT CRACKERS

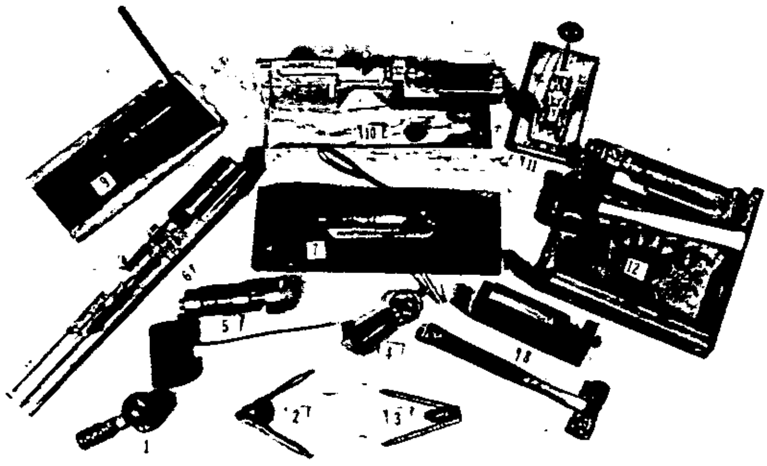


FIG. 99. TWELVE MODELS OF HOME NUT CRACKERS

(1) Wood screw to apply pressure on side of nut.
(2) & (3) Metal pincer to crack nut by pressure on side or end.
(4) Metal screw to apply pressure sidewise.
(5), (8), & (12) Horizontal plunger with impact applied to end of nut by one stroke of mallet.
(6) & (10) Same as above with force furnished by tension of large rubber band.
(7) Horizontal plunger activated by lever, to apply pressure on end of nut; adjusted to size of nuts by screw-cylinder.
(9) Same as (7) except home-made.
(11) Vertical plunger activated by lever to apply pressure at end of nut; adjusted to nut size by notches in upright staff.

and conveyors. The capacity of pecan shelling plants is unlimited in that double lines and multiple units may be used. For example, most cracking machines are built in multiples of ten.

Several modern pecan shelling plants have been built since 1960. Two of these were by the Gold Kist Pecan Company at Canton, Mississippi, and Waycross, Georgia. One of the largest plants is the Sunshine Pecan Company of San Antonia, Texas. This is a seven-story structure located adjacent to a 5,000,000 lb. cold storage plant. Pecans are conveyed by air to the top level and they flow by gravity to various processing stations to packaging (Kennerly 1966).

The plant operates the year round with a capacity of 7,000,000 lb. of pecan meats annually. The majority of the nuts used are seedlings from Texas, Oklahoma and New Mexico.

Courtesy Gold Kist Pecans

FIG. 100. PECAN MEATS RECEIVING FINAL INSPECTION BEFORE PACKAGING

A systematic sample of about 0.3% of the load is taken from every truck, cracked and tested. The sample tests are comprehensive enough to predict within one per cent what the quality and quantity of the total pecans will be when processed. From the receiving hoppers the pecans are transported by bucket elevators to be air-cleaned using a dust cyclone. Following cleaning, the pecans are moved by air conduction to the air fountain atop the building where bubbler action slows the pecans and drops them into one of 36 bins each 10 × 10 × 50 ft. They are held at 32°–34° F. with 60–70% relative humidity (Kennerly 1966).

Prior to 1930 the bulk of the pecan crop was sold in-shell and consumed in the South, but considerable quantities were shipped to northern markets during holiday seasons. (See p. 4).

PROCESSING WHOLE PECANS

Possibly the first pecan to be commercially polished and covered with paraffin were exhibited at the National Pecan Association in Albany, Georgia, in 1924. They were prepared by Bob's Candy Company (Anon. 1924). Soon afterwards the National Pecan Growers Exchange of Albany, marketed polished, bleached and dyed whole pecans with a phenomenal increase in sales due to improved appearance. The processing was said to last only about two minutes (Bullard 1934).

Processing in-shell pecans consists of grading for size and shape, bleaching by washing in wet sand to remove the black streaks and spots, polishing and waxing, and sometimes dyeing the shells.

Polishing in-shell pecans is a part of the processing industry separate from any other. It follows a series of automatic grading, blowing, washing, sanding, drying, polishing and inspecting the in-shell product. An antioxidant and dye may be applied to the shells of the nuts just before waxing and polishing.

The demand for polished pecans reached a height about 1940 and has since been declining in favor of shelled meats. However, pecans polished and dyed pink and packed in windowed cartons have remained popular for export. This is a favorite nut in England and Europe for Thanksgiving and Christmas holidays. To supply this seasonal demand, polishing plants operate continuously during October, November and December and remain almost idle the remainder of the year.

Only certain varieties, carefully graded for uniformity of size and shape are polished in-shell. Stuart is by far the most popular variety for this.

PECAN SHELLING INDUSTRY

Since 1930, pecan production has increased greatly and more have entered commercial channels. The increased use of pecans by food manufacturers and consumers has resulted in increased demand for shelled pecans. The number of firms which shell the nuts and sell graded and sized kernels in bulk and retail packages has expanded.

By 1960, there were approximately 80 pecan shelling firms in the United States, and they handled most of the pecans produced. During that year, the crop was 187.5 tons and more than 90% were shelled before marketing. Both the production and processing of pecans were operations carried on in conjunction with other farming and processing operations. For example, the shelling industry operated at only about 35% capacity. The low level of performance was due partly to small, part-time firms who operated only for the holiday season. The small firms operated at only about 10% of capacity, while the larger plants operated at 60% capacity. The large shellers became larger and the small plants quit shelling. In 1960, 8 firms sold over five million pounds each and accounted for 84% of the industry sales (Powell 1963).

Since 1960, pecan shelling plants have become larger and fewer operate practically the year round. This has been due to (a) refrigerated storage that provide a supply of good quality nuts the year round; (b) more mechanization that enable the operation to be done cheaper per man and per ton; (c) the demand for pecans for domestic and export has been constant throughout the year and has increased annually since 1960; (d) spreading the shelling operation out over the year more efficiently utilizes the labor, transportation and shelling facilities; (e) by storing pecans and shelling as needed enables the industry to operate smoothly over years of light and bumper crops (Woodroof and Heaton 1961).

Procuring a Supply of Pecans

Regardless of size, all shelling plants have the common problem of procuring an adequate supply of in-shell pecans each year. Even though pecans are produced in more than 11 states, the every-other-year production pattern of pecan trees increases the difficulty of maintaining a supply. Not all producing areas have a crop of pecans each year.

Thus, the larger pecan shelling firms have been forced to set up far-flung buying organizations to purchase their supply of nuts during the short harvest season in the fall. The farmers deliver the nuts to accumulators, who grade and bag them and sell them at auction sales or directly to shellers.

Because a large portion of the total pecan crop is produced on wild trees, forecasting the size of the crop is difficult. Since the size of the crop is unknown, and there is sharp competition among buyers in short crop years to obtain an adequate supply, the price for in-shell pecans is often forced up to unrealistic levels. Buying and selling in-shell pecans is highly speculative, and in years of heavy crop the price to the farmer is low and many low quality nuts remain unharvested.

High prices for in-shell pecans increase the kernel cost to the sheller. For example, a one cent increase in the cost of in-shell pecans increases the cost of pecan meats about three cents. The meats costs are also affected by the quality of the pecans. For instance, if the sheller pays 30 cents per pound for in-shell pecans, his meat cost is 85 cents a pound when the nuts yield 35% meat, but only 75 cents per pound if 40% is obtained.

Thus, pecan shellers operate under a great deal of uncertainty concerning the amount and average quality of pecans to be marketed each year (Powell 1963).

Equipment for Shelling Pecans

The capacity of a shelling plant is determined by the number of cracking machines used. Large plants operate as many as 80 cracking machines with a daily capacity of 60,000 lb., and a seasonal capacity of 8,000,000 lb.

Equipment necessary for operating a pecan shelling plant (See Fig. 101 & 102) consists of:

(a) grading and sizing machinery equipped with screens and blowers for removing faulty nuts and foreign materials, and for segregating the nuts into nine sizes with screen openings as follows: smaller than 9/16, 9/16, 10/16, 11/16, 12/16, 13/16, 14/16, 15/16 in. and larger;

(b) machines with vats or tanks for dipping and "conditioning" pecans for shelling;

(c) cracking machines, with a capacity of about 1,000 lb. of nuts per day each, which may be adjusted for different sized nuts and installed in series;

(d) shellers for separating the shells and meats;

(e) screens for separating halves and broken pieces of various sizes;

(f) dryers for removing excess moisture from meats;

(g) grading belts or tables for hand-picking the dried meats;

(h) electric eyes for grading the meats; and

(i) refrigerated rooms for storing unshelled and shelled pecans.

Conditioning Pecans for Shelling

To prevent shattering of the meats, pecans should be moistened or "conditioned" before cracking. This may be accomplished by either of two methods.

(1) The cold water method, which is generally used, in which the pecans are soaked for 20–30 minutes in water containing 1000 p.p.m. of chlorine, then drained and held 16–24 hours in sacks, vats, or barrels for cracking at any time within the next 24 hours.

(2) The steam pressure method, by which the pecans are subjected to five pounds steam pressure for 6–8 minutes, then cooled and held for 30–60 minutes. This method is fast, but less effective in controlling mold than the cold water method, may cause slight darkening and a faint cooked flavor.

(3) The hot water method, by which pecans are immersed for 20 minutes in water heated to 145° F., followed immediately by shelling, is fast and yields meats of excellent quality.

Wetting agents—sodium tetraphosphate, santomerse, or polyoxyethylene sorbitan triolate (Tween 85)—or vacuum, used in conjunction with the cold or hot water treatments, improves penetration of the shells and reduces the time the meats are wet.

During conditioning moisture enters the shell through the vascular system at the base and passes to the apex through the middle partition. The moisture content of the meats is raised from about 4 to 8%, and there is an increase in weight of the nuts of about four per cent. For most satisfactory cracking and shelling, the pecan shells should be dry, brittle and easily shattered, while the kernels should be limp and pliable.

An experiment was conducted to determine the effect of conditioning pecans before shelling on the stability of the meats. Nuts of the Stuart variety and a seedling were (a) soaked in water for 20 minutes and drained overnight and (b) shelled without conditioning. After shelling the pecan

TABLE 76

TWENTY-ONE METHODS OF "CONDITIONING" STUART PECANS FOR SHELLING, LISTED IN ORDER OF PREFERENCE, BASED ON PER CENT OF PERFECT HALVES; AND RATED IN ORDER OF PREFERENCE, BASED ON QUALITY (COLOR, TEXTURE AND FLAVOR) OF MEATS

Treatment	Time of Treatment	Time from Treatment to Cracking	Ease of Shelling	Structure of Shells	Structure of Meats	Unbroken Halves	Quality Score	Order of Preference Based on Quality of Nuts
	Minutes	Hours				%	%	Rating
Live steam	10	¼	very easy	very brittle	very limp	90	75.6	19
Steam pressure, 5 lb.	6	¼	very easy	very brittle	very limp	89	77.0	18
Live steam	15	¼	very easy	brittle	limp	86	72.9	21
Steam pressure, 5 lb.	12	¼	very easy	brittle	very limp	85	74.4	20
Steam pressure, 5 lb.	4	¼	easy	slightly tough	limp	83	86.7	16
Steam pressure, 5 lb.	8	¼	easy	brittle	very limp	81	81.1	17
Water, 70°	20	16	easy	brittle	slightly brittle	79	94.8	2
Water, 70°	30	16	very easy	brittle	slightly brittle	79	90.0	6
Air, 90% r.h.	1440	0	easy	brittle	slightly brittle	78	88.9	8
Live steam	5	¼	easy	brittle	limp	77	82.2	15
Steam pressure, 5 lb.	12	16	easy	brittle	slightly brittle	75	92.9	3
Water, 210°	5	¼	easy	brittle	slightly brittle	75	88.9	9
Water, 190°	20	¼	easy	brittle	slightly brittle	74	88.1	10
Water, 210°	5	¼	easy	brittle	slightly brittle	70	85.6	14
Water, 70°, 0-1% wetting agent	20	16	fairly easy	tough	brittle	65	91.9	5
Water, 145°	20	15	hard	tough	brittle	62	92.8	4
Water, 145°, wetting agent	20	¼	hard	tough	very brittle	62	95.8	1
Water, 145°, wetting agent	20	16	hard	tough	brittle	60	87.4	12
Water, 145°, vacuum	20	¼	hard to wet	tough	brittle	52	86.7	13
Water, 145°, vacuum	20	16	hard	tough	brittle	52	88.1	11
Water, 145°, vacuum wetting agent	20	¼	hard	very tough	brittle	52	89.6	7
None	...	...	very hard	tough	very brittle	51	94.4	...

meats were sealed in tin cans and stored at −20°, 32°, and 70° F. respectively for examination after 5, 10 and 13 months.

Results showed that conditioning was very beneficial: (a) by greatly reducing the amount of bruising and breakage of the meats during cracking and shelling; (b) by improving the appearance, resulting in a lighter color, and (c) by extending the stability of the nuts by about six per cent.

The pecans soaked before shelling were consistently rated higher in color, texture, and flavor than similar nuts shelled without soaking. The conditioned meats had a brighter color, more tender texture and better nut flavor. The results in favor of the conditioned nuts were statistically significant.

Cracking and Shelling Pecans

Cracking is accomplished by applying force to the ends of the nuts individually. Tests have shown that pecans of average shell thickness (Stuart) require more than 200 lb. of pressure on the ends to crush. Some varieties require as much as 600 lb. of gently applied pressure to crush.

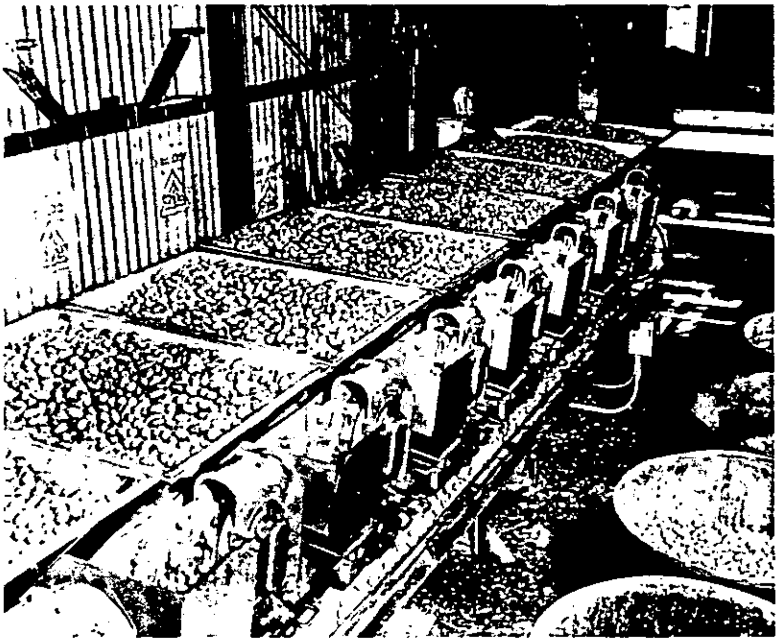
The mechanical crackers are plungers operated by levers and gears, and are amazingly efficient and fast when arranged in series or batteries as shown in Fig. 102. The pecans are cracked individually after they are oriented and struck by a plunger on the end. The plunger and anvil are hollowed so that the concussion (about ⅛ in.) causes the sides of the shell to crack longitudinally into about eight "barrel stave" pieces, each of which breaks in the middle. Thus, the shell of each nut is broken into about 16 pieces without crushing or breaking the meats. The blow from the plunger exerts pressure, not on the tip of the nut, but on a circular area around the tip about ½ in. in diameter. The halves are broken apart by shakers liberating the middle partition.

Crackers shown in Fig. 101 have a plunger with about ⅛ in. play. When placed firmly against a nut before being struck, this is sufficient distance to crack the nut, at the same time it protects the nut from being crushed irrespective of the weight of the blow.

Commercial shelling plants have batteries of crackers, each adjusted to nuts of specific sizes. A battery of 15 crackers as shown in Fig. 102 will crack 10,000 lb. of small seedlings and 15,000 lb. of large nuts per day.

By passing the cracked nuts over a labyrinth of conveyors, to shellers, blowers, reels, fans, blowers, graders and pickers, the meats and shells are separated.

The shelled pecans are separated into grades based on the size of halves or pieces as shown in Figs. 105 and 108. Sizing is accomplished by passing the meats over a series of rapidly vibrating screens with holes of progressively larger diameter. Halves are of eight sizes, based upon the number



Courtesy Minehan Pecan Co.

FIG. 101. BATTERY OF EIGHT MACHINES THAT CRACK MOISTENED PECANS LENGTHWISE, INDIVIDUALLY, AT A HIGH RATE OF SPEED

The nuts are then carried, automatically, by conveyor belt to shakers and screens for removal of the shells.

Courtesy Gold Kist Pecans

FIG. 102. A BATTERY OF 15 PECAN CRACKERS

All of the nuts of this lot are of the same size and after being cracked are discharged on a single belt to the shellers.

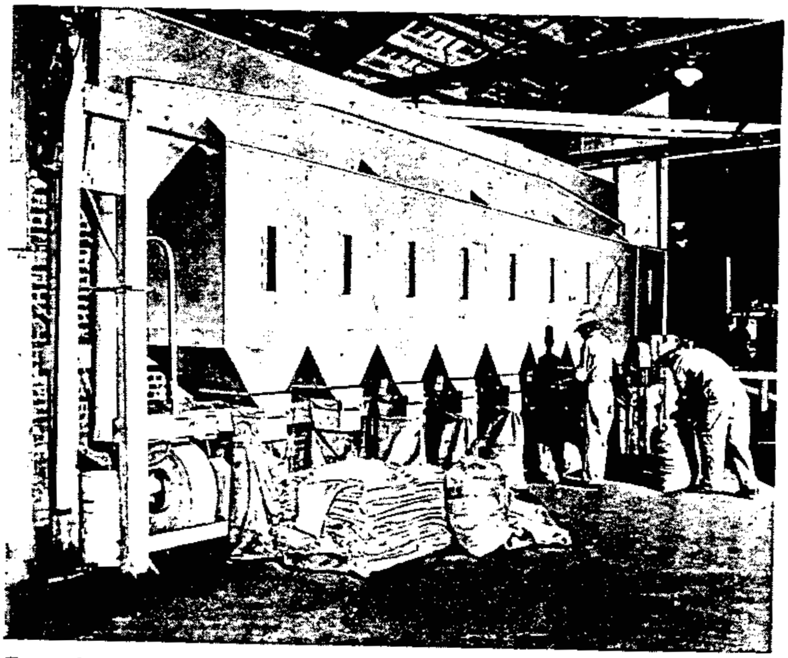


FIG. 103. UNIT FOR SEPARATING FRESHLY HARVESTED PECANS INTO NINE GRADES, ACCORDING TO SIZE; AND FOR REMOVING "POPS" BY AIR BLAST

per pound: mammoth, 200 to 250; junior mammoth, 251 to 300; jumbo, 301 to 350; extra large, 351 to 450; large halves, 451 to 550; medium halves, 551 to 650; small halves, 651 to 750; small topper halves, 751 and up. Broken or cut meats are of eight sizes. From the largest to smallest sizes of pieces, they are: mammoth, extra large, large, medium, small, midget, granules, and meal.

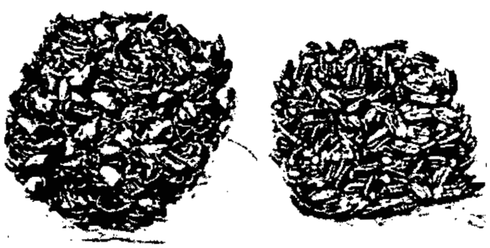


FIG. 104. PECAN SHELLS HAVE 56% OF THE WEIGHT AND 71% OF THE VOLUME OF THE NUTS; THE MEATS HAVE 44% OF THE WEIGHT AND 50% OF THE VOLUME OF THE UNSHELLED NUTS

When 38 lb. of Stuart pecans were shelled, 49% by weight were meats and 51% shells. The meats occupied 61% as much space as the unshelled nuts, and the shells occupied 72% as much space. The space required for the meats and shells was 40% greater than that for the unshelled nuts.

Drying Pecan Meats

Pecan meats when shelled contain from 7 to 9% moisture. To maintain quality in the meats this must be reduced to four per cent or lower. Experience has shown that this may be done by rapidly circulating dry air through the meats.

To determine the influence of the temperature of the drying air on the quality and shelf-life of pecans, 22 lb. of freshly shelled, graded, and undried Stuart halves were obtained from a commercial shelling plant. They were separated into two-pound lots and dried to a moderate moisture level in rapidly circulating air, as outlined in Table 77. Each lot was evaluated for moisture and quality immediately after drying, and for quality after six months storage at 32°.

TABLE 77

EFFECT OF TEMPERATURE OF DRYING PECAN MEATS, FROM 7.49 TO 4.06% MOISTURE OR LOWER, ON THE QUALITY OF MEATS BEFORE AND AFTER STORAGE FOR SIX MONTHS AT 32°F

Drying			Quality	
Temperature	Time	Moisture	Before Storage	After Storage
F.	Hr.	%	Score (100)	Score (100)
170°	48	4.06	88.9	88.9
20°	168	3.78	88.9	88.9
0°	168	3.83	88.9	88.9
80°	15	3.56	88.9	88.9
100°	2¾	4.16	86.7	85.6
120°	1¾	3.59	85.6	86.7
140°	1¼	3.44	83.3	82.2
160°	1	3.14	84.4	81.1
180°	¾	2.65	83.3	76.7
200°	½	2.76	84.4	71.1

When drying temperatures of 120° to 140° and higher were used, oil migrated to the surface of the meats resulting in a greasy appearance, a dry and slightly tough texture, and a slightly cooked flavor which became stale during storage.

The rate of moisture loss from pecan meats during drying at 200° was approximately 1.5, 2.0, 2.75, 4.3, 10.4, and 35.0 times faster than at 180°, 160°, 140°, 120°, 100° and 80°, respectively.

Another experiment was set up to determine the equilibrium moisture content of pecan halves at various storage temperatures and air humidities. Before storage the moisture content of pecan halves was adjusted to low (1.6% and 2.18%), medium (4%), and high (6.7%) moisture levels. These pecan halves were placed in wire baskets (in duplicate), stored at each of the temperature and relative humidity conditions, and weighed at weekly intervals until they reached a constant figure. The final moisture content of the meats was determined as shown in Table 78.

TABLE 78

THE INFLUENCE OF TEMPERATURE AND RELATIVE HUMIDITY ON EQUILIBRIUM MOISTURE CONTENT OF STUART PECAN HALVES

Storage		Pecan Meats	
Temperature	Relative Humidity	Initial Moisture Content	Equilibrium Moisture Content
F.	%	%	%
20°	45–50	2.58 medium	3.78
0°	55–60	2.58 medium	3.61
0°	65–70	1.67 low	4.46
0°	65–70	2.18 low	4.57
0°	65–70	6.37 high	4.76
15°	55–60	7.45 high	3.71
20°	60–65	2.58 medium	3.50
20°	75–80	1.67 low	6.34
20°	75–80	2.18 low	6.77
20°	75–80	6.37 high	6.18
25°	70–75	1.67 low	3.90
25°	70–75	2.18 low	3.87
25°	70–75	2.58 medium	3.90
25°	70–75	6.37 high	3.92
32°	35–40	3.41 medium	2.34
32°	65–70	3.41 medium	4.94
32°	75–80	1.67 low	4.75
32°	75–80	2.18 low	4.91
32°	75–80	2.58 medium	4.51
32°	75–80	6.37 high	5.07
50°	50–65	7.20 high	3.00
70°	50–65	7.20 high	2.80

Data showed that pecan halves with high moisture content dried to a safe moisture level of four per cent or lower during storage at −20°, 0°, 15°, 20°, 32°, 36°, 36° and 70° F., when the relative humidity was 45–50, 60, 60, 65, 75, 75, and 75%, respectively, and forced air circulation was maintained throughout the storage rooms. The data also showed that dry pecan halves increased in moisture to a desirable level when stored under these conditions.

In a third experiment the rate of drying pecan meats while in freezing storage was studied by placing 30-lb. cases of meats in storage at 15° F., with 45% relative humidity. Halves of Curtis pecans were reduced from 7.45% moisture to 3.85% in 15 days; halves of Van Deman nuts were similarly reduced to 3.81%; and pecan pieces were reduced from 9 to 2.5% moisture. It was found that pecan halves held at 45% relative humidity for more than two weeks, and pieces held at this humidity for more than one week, became excessively brittle, and complaints of breakage of meats during shipping came from customers. It was concluded that refrigerated-drying should be done at 15°-25° with 45% relative humidity for one to two weeks, and storage should be at 28°-32° F. with 60-65% relative humidity for below freezing temperatures and 70% relative humidity for above freezing temperatures.

From these experiments on drying pecan meats it was concluded that:

(a) Moisture content of pecan meats may be increased or decreased by subjecting them to blasts of air with high or low humidity.

(b) Optimum relative humidity was 60-70%, causing the moisture content of the meats to equalize at 3.5-4.0%.

(c) Drying meats with hot air was fast, but the quality of the meats was adversely affected when the meats were dried at temperatures of 120° F.

(d) Drying meats with refrigerated air was slow, but those dried at 32° F. or lower retained natural appearance, aroma, color, and flavor in storage much longer than did those dried at 70° F. or higher.

GRADING PECAN MEATS

Pecan meats are sold by grades and the grades determine the suitability for use—in bakery goods, salting, confections, ice cream, consumer packages or other uses.

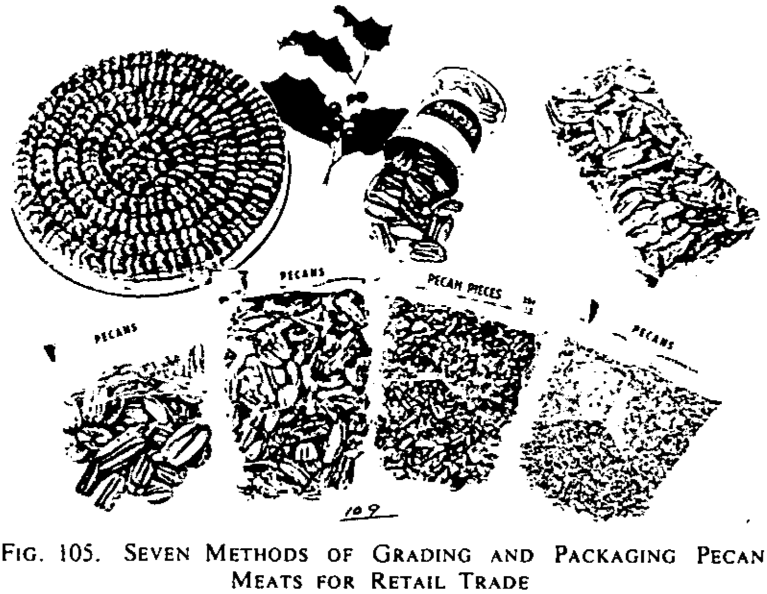


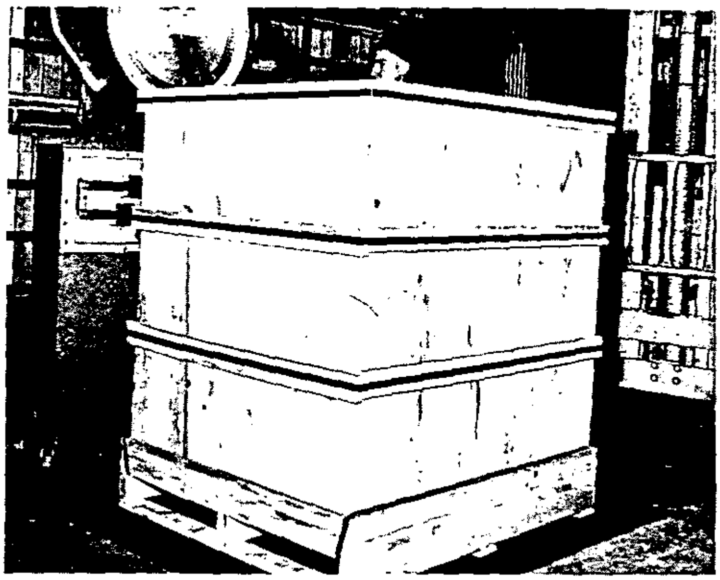
FIG. 105. SEVEN METHODS OF GRADING AND PACKAGING PECAN MEATS FOR RETAIL TRADE

The first general grades are halves and pieces. There are many uses for which only halves are suitable; these include pecan pies, salting, and topping for cookies and candies, especially pecan brittle. For these purposes it is important to know the number of halves per pound, and this is one basis for grading as discussed on p. 126 and in Appendix 5. In general there is a premium price for grades with a large number (500 or more) of halves per pound. Since seedlings are smaller than most improved varieties, the former may bring higher prices per pound. Since seedlings are grown mostly in Texas, Oklahoma and Louisiana, a buyer wishing small pecan halves should look to that area.

Since about 1950, the demand for pecan pieces has been greater than the supply and many larger halves have been cut into pieces of designated sizes. This demand has been for ice cream, cookies, pralines, candies and home use for making dozens of recipes for desserts, salads, topping and others. The demand for cut or broken pieces has also increased with the increase in production of varieties of large nuts such as Mahan, and Farley.

Practically all pecan crackers now produce 4 to 6 grades of halves and pieces of 4 to 6 sizes as described on p. 126.

Machines are available for cutting or breaking, and grading pecan pieces for size and color. End-users and home makers can purchase pre-graded pecan halves and pieces in almost any desire quantity, throughout the year.



Courtesy Gold Kist Pecans

FIG. 106. A KNOCK-DOWN TYPE TOTE-BOX HOLDING 1,500 LB. IS USED FOR FORK LIFT HANDLING PECANS IN SHELLING PLANTS

Courtesy Gold Kist Pecans

FIG. 107. PECANS ARE AUTOMATICALLY DUMPED FROM TOTE-BOXES INTO HOPPER FOR GRADING

FIG. 108. SHOWING TWELVE GRADES OF PECAN MEATS

The stability of pecan meats is reduced by increasing the surface exposure consequently the smaller the pieces the shorter the time before staleness and rancidity set in. For this reason pecans that are to be cut into pieces should be held under refrigeration in the shell, and shelled and cut to fill immediate orders.

SEPARATION OF NUTMEAT FRAGMENTS FROM SHELL FRAGMENTS

In a conventional commercial method of providing shelled nutmeats, whole nuts are initially passed through a suitable breaking machine which breaks the shell and provides access to the nutmeats (Sanlilippo *et al.* ...). In the breaking process the shell is reduced to fragments but much of the nutmeat is also broken. The resulting produce therefore consists of a mixture of shell fragments, nutmeat fragments and unbroken pieces of nutmeat which, in the case of pecans, walnuts, etc., are actually nutmeat halves and wholes. The unbroken nutmeat halves and wholes are then separated from the shell and nutmeat fragments by an air classification process which utilizes an air stream to carry away the lighter shell and nutmeat fragments, leaving the larger nutmeat halves and wholes behind. The nutmeat fragments are then separated from the shell fragments and the latter are discarded.

At the present time, the separation of shell and nutmeat fragments is accomplished by one of two methods. In accordance with one of these methods, the nutmeat and shell fragments are placed on a moving conveyor and caused to pass under a cylindrical roll provided with a plurality of outwardly projecting needles. The needles impale the nutmeat fragments but not the shells, thus removing the nutmeat fragments from the mixture while allowing the shell fragments to proceed past the roll and to be discarded. The nutmeat fragments are removed from the roll as it rotates. As can be appreciated, many of the nutmeat fragments are not susceptible to being impaled in this manner and thus are lost with the shell fragments. In addition, this method and apparatus cause an exceptionally large amount of breakage and mealing of the fragments. It is estimated that as much as 10% of the nutmeats, by weight, are thus lost. ... It is difficult to preserve sanitary conditions while performing this method.

In accordance with the other of these methods, a batch of nutmeat and shell fragments is placed in a large vessel partially filled with water. The vessel is sealed and a vacuum is drawn, removing entrapped air from the shell fragments so as to permit them to sink. The nutmeat fragments are buoyant, however, and their buoyancy is retained in the presence of the vacuum. The shell fragments settle to the bottom of the vessel and the nutmeat fragments float.

Sanlilippo *et al.* (1966) have recently invented an apparatus for continuously separating naturally buoyant fragments of nutmeat from a mixture of such fragments and fragments of nut shell which are not buoyant in a vacuum environment.

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Processing Pecans

INTRODUCTION

Throughout the harvest season the grower sells his pecans to a dealer or accumulator who collects from several thousand pounds to more than a million pounds in various producing areas.

Those that are to be processed are moved as quickly as possible to shelling plants, where they are stored and processed the year round. During processing, they are passed through a series of highly mechanized operations. These include conditioning, cracking, shelling, picking, grading, drying, packaging, and sometimes restoring.

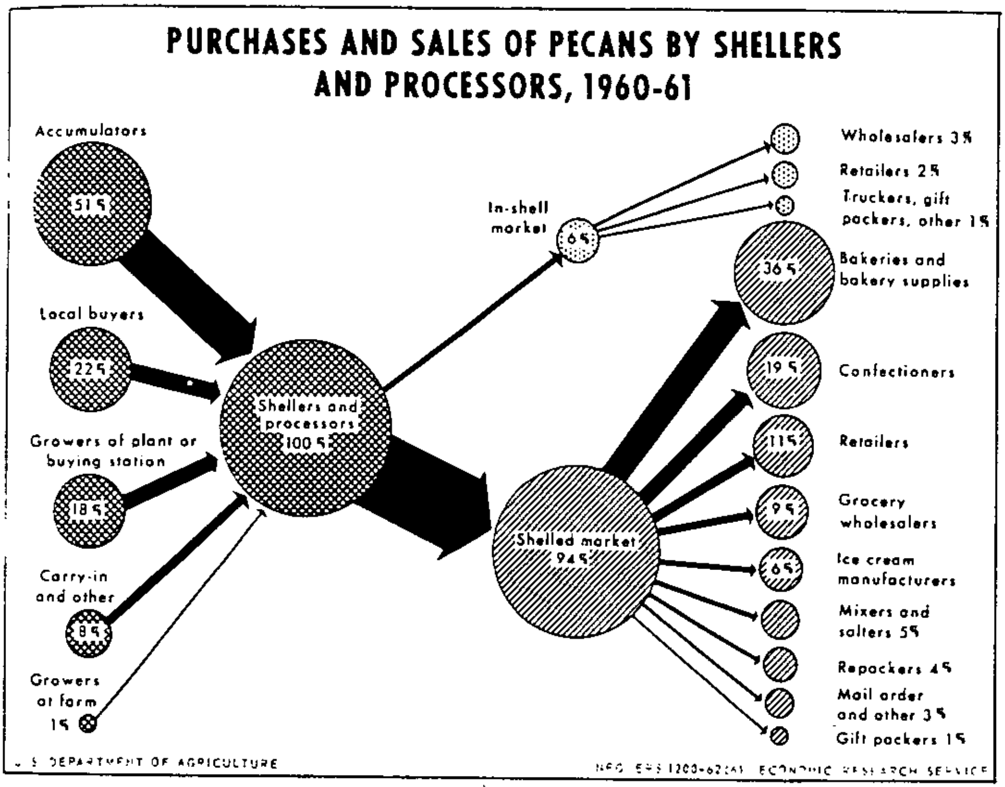
Courtesy B. F. Goodrich Co.

FIG. 121. FINAL INSPECTION OF SHELLED PECANS IS BY HAND

Here the screened nuts are inspected on sanitary rubber belts.

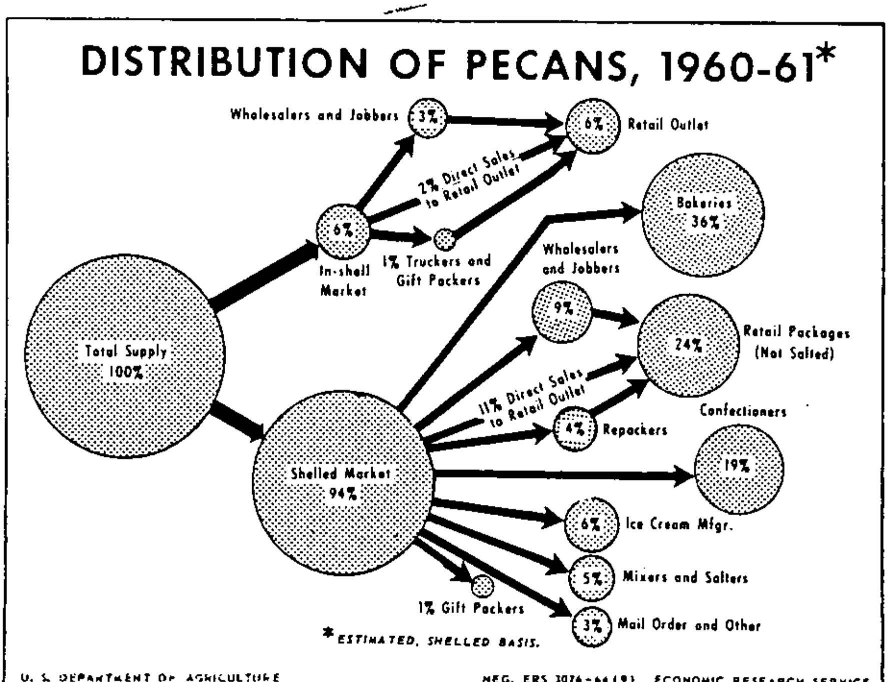
From the sheller or refrigerated storage warehouse the nuts move continuously to the end users—ice cream manufacturers, bakeries, confectioners, salters and retailers.

Processing pecans after shelling consists essentially of subjecting them to conditions that would preserve all the good qualities and prevent de-



Courtesy U. S. Dept. of Agr.

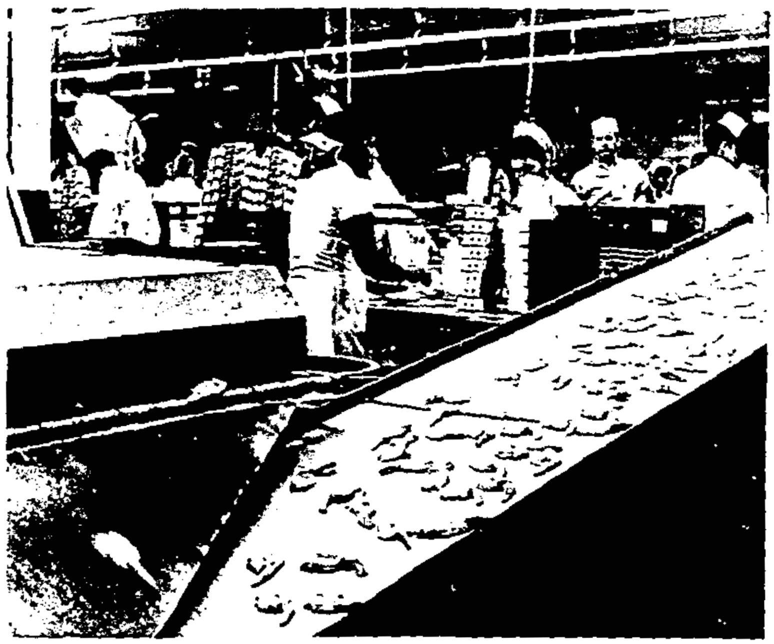
FIG. 122. PURCHASES AND SALES OF PECANS BY SHELLERS AND PROCESSORS, 1960–61



Courtesy U. S. Dept. of Agr.

terioration until they reach the end-users or consumers. It includes treatments for protecting the meats from rancidity, insects, mold and chemical degradation. Much of this was discussed under "storing pecans" and will be dealt with in more detail under "salting pecans."

As the pecan industry increases in size, as the export market grows, and as more food products are made from pecans on a year round schedule, pecan processing will become more important.



Courtesy A. B. Kinnerly, Canner/Packer

FIG. 124. PECAN BREADED SHRIMP BEING PREPARED FOR FREEZING

Fish and chicken are breaded in a similar manner.

RANCIDITY IN PECANS

The high oil content of pecans (65 to 75%) renders them susceptible to rancidity. This limits the number of products made from them as well as the length of time they may be held. Development of rancidity is the most common cause of degrading pecans. Rancidity is accompanied by staleness and loss of fresh aroma and flavor. It is a gradual and continuous process first noticed in unshelled pecans held at 70° F., for about four months, and held at 34° F. for about two years. Four methods of testing for rancidity in pecans, in order of preference are: sensory evaluation, the Kreis test, free fatty acid values and peroxide number (Assoc. Offic. Agr. Chem. 1960). Along with rancidity there is reddening or browning of the seed coats (See Appendix).

A very mild, but detectable, rancid odor or flavor may not be objectionable in products that have flavors or odors which tend to mask rancidity. This is especially true with pecans in fruit cakes, spiced pecans or chocolate coated pecans.

Excessive drying seems to accelerate rancidity, possibly by replacing oxygen for water in the tissue. Pecans seem to be more stable at relative humidities from 75 to 80% and at moistures of about $4\frac{1}{2}\%$, or just short of molding.

Rancidity is used to describe many undesirable aromas and flavors developed in fats and oils, whether extracted or still contained in the nuts. It includes rank or tainted smells or tastes that are associated with oxidation or hydrolysis, and is usually accompanied by partial decomposition and formation of free fatty acids.

Three classes of rancidity are (a) hydrolysis of component glycerides of fat into free fatty acids and glycerol or mono- and diglycerides, (b) oxidation of double bonds of unsaturated glycerides to form peroxides and then decompose to aldehydes of objectionable odors and flavors, and (c) β-oxidation of free saturated fatty acids.

There is no single method for determining rancidity in nuts and nut products. In most cases smell and taste are sufficient. Chemical tests include the Kreis method, determination of 2-thiobarbutric acid, peroxide values, photochemical methods, determining total carbonyl compounds. These methods are described in proceedings of Association of Official Agricultural Chemists (1960). A more recent procedure is the use of gas chromatograph.

RETARDING RANCIDITY IN PECANS

One of the most effective ways of retarding rancidity in pecans is by refrigeration. See section on pecan storage p. 134. They can be held from one season to the next by storing at 32° F. with 70–75% relative humidity (Blackmon 1932; Brison 1945; Wright 1941; Woodroof and Heaton 1961). At 50° F. they remain good for six months, and at 70° F. for about four months. The nuts must be harvested in the fall and stored before oil begins to leak out of the kernels or staleness begins.

A second method of retarding rancidity is by excluding air. This may be done by the use of hermetically sealed containers; packing under 25 in. or more of vacuum; by replacing the air in the containers with 97% inert gas such as nitrogen or hydrogen; or by coating the nuts with collodion or water glass. By excluding a high percentage of the air from the nuts the storage life may be extended 2 or 3 times, depending upon the amount of air excluded. Syrups and sugar coatings are fairly effective in excluding oxygen. This is especially true with pecans in candies and fruit cakes (Cruess and Armstrong 1947).

A third method of retarding rancidity in pecans is by the use of antioxidants as described in Table 82 and on p. 158. Fresh pecans contain about .45% of tocopherols, a naturally occuring antioxidant, which renders pecans quite stable for a while, depending largely on the temperature. Added antioxidants (0.1% of NDGA or BHA) are of more value in slightly aged pecans after the natural antioxidants have partially disappeared. Godkin *et al.* (1951) reported that the bitterness contributed by NDGA is undesirable and nullifies the efficiency of its rancidity delaying properties as an antioxidant.

TABLE 82

ANTIOXIDANT FORMULAS

Antioxidant I		
Butylated hydroxyanisole	20%	
Butylated hydroxytoluene	20%	
Vegetable oil	60%	
Antioxidant II		
	% of	
Component	Solution	Total Solids
Dipotassium salt of ethylenediamine tetraacetic add	0.024	0.20
Citric acid	0.048	0.40
Butylated hydroxyanisole (BHA)	0.24	2.0
Butylated hydroxytoluene (BHT)	0.24	2.0
Propyl gallate	0.24	2.0
Sorbitan monostearate (Span 60)	0.52	4.4
Polyoxyethylene stearate (G-2147)	5.12	43.0
Polyoxyethylene sorbitan tristearate (Tween 65)	5.47	46.0
Isopropyl alcohol (91%)	88.1	...

Heating pecan meats extends freshness.—Woodroof and Heaton (1961) and McGlammery and Hood (1951) reported that pecan meats heated to an internal temperature of 176° F. in dry air or in oil doubled the shelf life by inactivating oxidative enzymes. Heating to higher temperatures produced a partially cooked flavor.

Heating pecan meats to 365° F. for 15 minutes, by dry roasting or with infrared heat rays, destroys natural antioxidants but increases the aroma and flavor many times. Roasting in oil is slightly less satisfactory for flavor development.

Finely grinding roasted pecan meats and packing in jars to exclude air increased the storage life by more than 20 times, without refrigeration. Freshness was extended much longer when an antioxidant was added and refrigeration was used.

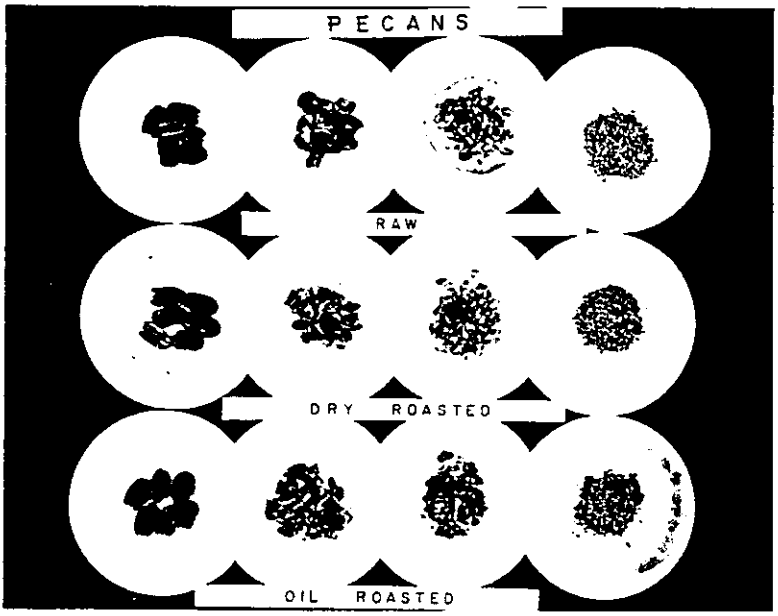


FIG. 125. PECAN HALVES AND PIECES; RAW, DRY ROASTED AND OIL ROASTED

Samples are spread on absorbent paper to show how roasting and chopping increases the "crawling" of the oil.

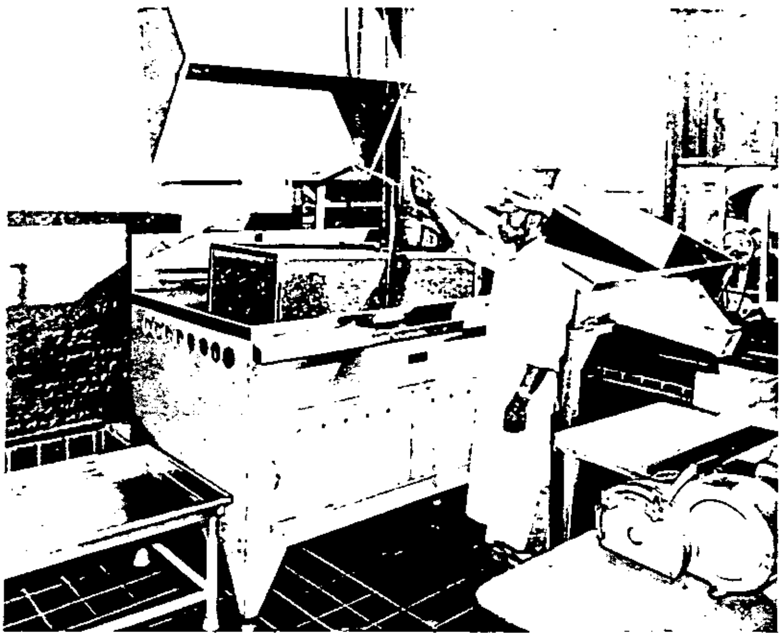


FIG. 126. BATCH, OIL ROASTING PECAN MEATS

Other methods of retarding rancidity in pecan meats are by storing in the dark, and by the use of containers coated on the inside with an antioxidant.

It has been established that storage life of nuts and oils can be extended if antioxidants are added. BHA, BHT, and propyl gallate are among the chemicals now being used for this purpose. These antioxidants, used with nuts and oils or fat containing foods, present problems such as being only partially effective with highly unsaturated oils, discoloration with metals, odors (particularly associated with phenolic-type antioxidants), and poor solubility.

Sherwin and Thompson of Eastman Chemical Products, Kingsport, Tennessee, proceeded to develop what they report as a more effective antioxidant primarily for polyunsaturated oils. This product is tertiarybutylhydroquinone (TBHQ).

A rapid and efficient method of stabilizing pecan nutmeats with antioxidants, primarily for bakeries was worked out (Anon. 1958). It was determined that nutmeats treated with Tenox BHA and Tenox BHT and used in bakery products had about twice the shelf-life of nuts not treated. Since the cost of adding the antioxidant at the shelling plant was light, the added shelf-life tended to increase the use of pecans in cookies, fruitcakes and other bakery items.

For complete control of rancidity in pecans and pecan meats several of the following procedures should be followed:

(1) Dry kernels to 4½% moisture as soon after maturity as possible using circulated air not higher than 100° F.

(2) Store at 38° F. or lower, with 65% relative humidity for pecan meats and 75% relative humidity for in-shell pecans.

(3) Heat to 176° F. for two minutes to inactivate oxidative enzymes.

(4) Reduce oxygen in the atmosphere by placing under vacuum, or in 98% nitrogen or carbon dioxide.

(5) Treat nuts or nutmeats with 0.1% BHA, BHT, or NDGA antioxidant.

(6) Coat nutmeats with sugar glaze, heavy syrup, zein, dextrins or collodion to exclude air.

(7) Pack in containers coated on inside with BHA, BHT or NDGA antioxidant.

(8) Keep in the dark or in amber colored containers.

RECOVERY OF PECAN OIL

Pecans and other tree nuts, although rich sources of oil, must be considered primarily as luxury food items, and edible grades cannot therefore be pressed economically except to fill small demands for specialty oils. Shelling plants, however, reject large amounts of moldy and otherwise inedible meats which are entirely suitable for oil recovery. The shells contain a considerable percentage of unseparated meats, which are reclaimed by reducing the shells in a hammer mill, screening and pressing (Kester 1949).

Pecan oil is a by-product of several operations in pecan processing. It is recovered from pecans and most tree nuts for limited use in cooking, cosmetics and other special preparations. The quantity of nut oil is small as compared to that of cottonseed, soybeans, corn and peanuts, and its recovery is justified on the basis of special flavor, chemical and physical qualities.

The source of nuts for oil recovery is (a) "meal" resulting from chopping or breaking the meats; (b) "screenings" from shelling operations containing a mixture of shells and meat particles; (c) nuts rejected from grading operations because of shape, size or defects. Clean pecan meats or meal run as high as 76% oil as shown in Tables 34 and 37 (p. 72 and 77).

The method of treatment and recovery varies with the kind of nuts but all follow the same general procedure for all tree nuts: (1) hulling or shelling the nuts; (2) removal of foreign materials, as shells, stones, pieces of wood or metal, from the meats; (3) rolling, crushing or chopping the material; (4) heating in moist air or steam; (5) removal of oil by hydraulic pressing, screw pressing, cage pressing or solvent extraction, or a combination of two or more of these; (6) removing foreign material by filtering; (7) refining by removal of free fatty acid with alkali and foreign odors with steam.

Costa and Mota (1942) indicated that, for the extraction of Brazil nut oil, screw pressing was very efficient and more practical than solvent extraction because with the latter the oil retains traces of the solvent and the fat-soluble vitamins are completely removed from the meal.

Pecan meal resulting from shelling amounts to about three per cent of the pecans shelled. It is a mixture of fine particles of meats and shells and is inedible. It contains about 30% oil which may be recovered by grinding and pressing or solvent extracting. The oil is of excellent quality.

The meal is collected from shelling plants throughout the industry and shipped to one or more central points for processing. Due to the large surface exposure the meal may become stale within a few weeks at room temperature. While the quantity of pecans shelled increases almost annually, the percentage of meal decreases constantly due to improvements in pecan processing equipment. For this reason the production of oil from pecans or most tree nuts is not increasing.

Kester (1949) reported about 300 tons of pecan oil produced annually. This quantity has increased little if any in 20 years. The refined oil sold for 40 to 50 cents per pound. He reported the composition of the oil as follows: iodine value, 100–106; oleic acid 70.9–77.8%; linoleic acid, 15.8–25.2%; saturated acids 4.0–5.1%; and unsaponifiables, 0.4% (see Table 34).

Whitehead and Warshaw (1938) extracted and refined pecan oil which was transparent, bland, odorless, and comparable to olive and other high grade oils. There was no rancidity development in the oil after 12 months storage in glass bottles exposed to sunlight at room temperature. They found that the oil could be used to make excellent French dressing, mayonnaise, and cold cream, and could be substituted for other cooking fats. The meal left after oil extraction could be made into tasty muffins, biscuits, bread, and cookies, as well as blended with common flavors. The oil contained the following (as percentages): oleic acid, 77.8; linoleic acid 15.8; myristic acid, 0.04; arachidic acid, 0.09; palmitic acid, 3.14; stearic, 1.82; cholesterol, 0.28; and lecithin, 0.5.

A ton of high quality pecans will yield approximately 400 lb. of a clear high quality golden oil when subjected to 12 tons pressure. When a good grade of pecans is used the press cake or pomace left after the oil is pressed or extracted, may be ground into a good flavored meal. This meal is used in candies, cakes, breads and possibly to produce breakfast foods and other products lower in calories than when regular pecan meats are used. Also, the pomace or unpressed pecans may be finely ground into a pecan butter (Blackmon 1937).

Another source of pecan meal from which oil may be recovered is from cutting and breaking operations when pecan meats are converted into smaller sizes. This meal is sieved from the pecan pieces and marketed for use in ice cream, cookies, candies and other recipes. It contains a higher percentage of torn seed coats and consequently is slightly bitter due to the tannin. The oil content runs about 60%.

The yield of edible meal from cutting operations varies from 2 to 5% depending upon the quality and condition of the meats and the fineness to which they are cut.

SOLVENT EXTRACTION OF OIL

Solvent extraction of oil from pecans and other nuts has the advantage that oil removal is more complete, and has the disadvantage that solvent soluble vitamins and other materials are removed from the meal. Solvent extraction is desirable when good quality nuts are used for making edible nut meal or flour.

Solvent extraction includes the steps of leaching the oil from the solid residue and subsequent recovery of solvent-free oil and meal. A good extractor must meet the following specifications: (1) it should extract substantially all the oil from the prepared seed, using an economical solvent seed ratio; (2) it must be mechanically strong, and capable of continuous operation for many months without maintenance; (3) it must operate simply and automatically; (4) it should cause a minimum of particle size reduction in the solids; and (5) it should produce a miscellanea of maximum clarity possible.

There are two types of solvent extractors, the immersion-type and the percolation-type. In the immersion-type the solids are agitated in the solvent while in the percolation-type the solvent is run through fixed beds of solids. In each of these the contacting between solvent and solids may be either continuous or stage-wise, with partial draining of the solvent from meats between stages. In all cases the flow of solvent and solids is made as counter-current as possible.

Each type has application where it has peculiar advantage. The percolation requires that the solids form a porous bed through which solvent can flow. This limits its application to well-prepared flakes or sized particles whereas the application of the immersion type is not limited. However, where the percolation-type can be used, it has the advantage of producing clear miscellanea by the filtration through the bed characteristic of its operation; of permitting adequate drainage by gravity, within the extractor, of the solvent in the extracted flakes; and of causing little reduction of particle size. The immersion-type generally requires auxiliary miscellanea clarification and auxiliary means of draining solvent from extracted solids, such as drain boards, squeezers and centrifuges.

In practice, the distinction between the two types of extractors is not sharp since an effort is made in the design of several of the immersion extractors to establish a bed and to gain the advantages of percolation.

There are many extractors described in patent literature; among which are the following:

- The Centrifuge Extraction System
- Horizontal Cell Extraction
- The Screw Conveyor
- Verticle Column Tray Extractors Systems—
  Allis-Chalmers, Anderson and Bonotto
- The Basket Extractor
- The Rotocel Extractor

Each of these has special advantages for certain oily seeds and size of operation (Karnofsky 1949).

Improved Oilseed Extractor

An efficient, vapor-tight, flake-feeding device for nut oil extraction was developed and may replace conventional equipment (Patton 1958). The design provides improvement over conventional screw-conveyor feeders by using an anti-bridging distributor conveyor in the hopper, and by using the material being fed to form a plug-type positive vapor seal at the discharge end of the feeder. The unit is self contained and consists of a hopper, a distributor [illegible], a main feed screw, a variable speed mechanism and an electric motor. A desirable feature is that the unit eliminates bridging of the flakes above the feed screws and consequently insures a continuous flow of material.

A short tubular extension is used at the discharge end of the screw through which the ground nuts can be forced, allowing them to compact gently and form a plug. This plug of nutmeats serves as a seal against the leakage of solvent out of the system, and also prevents the passage of air into the system.

REFINING PECAN OIL

In the refining process the crude pecan oil is treated with a solution of caustic soda (sodium hydroxide) to neutralize the free fatty acids and precipitate much of the undesirable coloring matter. The alkali combines with the free fatty acids and with part of the oil to form a stock called "foots" which is removed by centrifuge.

The hot refined oil is mixed with a small quantity of bleaching clay and run through a filter press to decolorize it. It is deodorized by heating under vacuum and then steam distilled. The resulting product is bland, tasteless, almost colorless and much more stable than crude oil. The time before staleness and rancidity begins can be extended by as much as five times by adding an antioxidant. It can again be doubled by packing under vacuum, doubled again by storing in the dark, and extended almost indefinitely by a combination of all of these with storage at 32° F. or lower.

USES FOR PECAN OIL

Pecan oil is competitive with most vegetable oils—peanut, corn, safflower, cotton and soybean—for uses in the diet. These include deep fat frying, hydrogenation, use in shortening, oleomargarine and others. However, pecan oil along with oil from other tree nuts—almond, Persian walnut, filbert, black walnut, cashew, macadamia, pine, and hickory—cannot compete pricewise with oil from the above named sources. There are a few chemical, physical and flavor properties in crude pecan oil that may give it an advantage in cosmetics, pharmaceuticals, and other specialty uses; but many of these characteristics are lost during the various steps in refining.

While pecan oil may be used in diets specifying a high degree of unsaturation; there are other, and cheaper, oils with the same properties.

USES OF PECANS

Following is the approximate breakdown of the uses of pecan meats:

	%
Bakers, fruitcakes, pies, cookies, cakes, sweet rolls	44
Confectionery manufacturers, many kinds	20
Ice cream manufacturers	12
Transparent bags, halves, pieces, meal	12
Nut salters, often mixed with other nuts	7
Others	5
Total	100%

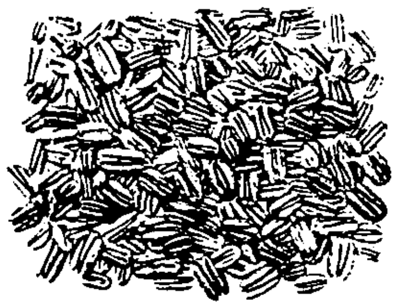


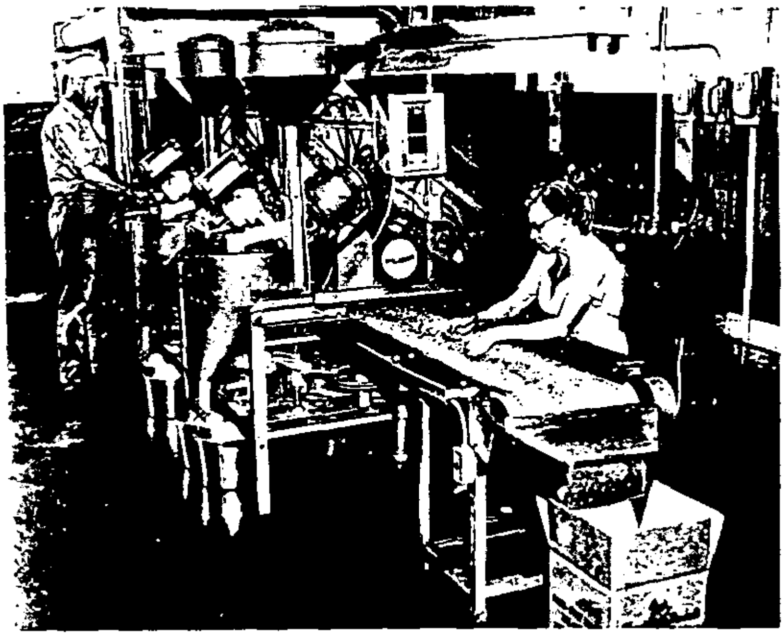
FIG. 127. PECAN HALVES THAT ARE USED IN MORE THAN 100 PRODUCTS

FIG. 128. ONE TEASPOON OF PECAN BUTTER ADDS EXCELLENT FLAVOR, SMOOTH TEXTURE AND A "NUT MEG" APPEARANCE TO MILKSHAKES

COLOR MEASUREMENT OF NUTS

Color is light energy that is reflected from the object being viewed; or, the color of the object is the color reflected from the object. The control of color quality in fresh, stored or processed nuts is very important.

Color measurements of nuts and nut products are made by one or more of four methods: (a) purely subjective, (b) comparatively subjective, (c) comparatively objective and (d) purely objective.



Courtesy Tracy-Luckey Co.

FIG. 129. ELECTRIC EYE MACHINES SEPARATE PECAN PIECES ACCORDING TO COLOR

The two units shown may replace 10 people grading by hand.

Purely Subjective Color Measurements

These are made by individuals using sensory facilities in conjunction with memory data to form a qualitative conclusion. Even with a wide array of instruments available, color measurements of nuts, and nut products are often made through the sensory instruments of recognized color inspection experts who have "an eye for color."

Comparatively Subjective Measurements

These are made through visual comparison of samples with accepted standards. The standards may be in the form of color charts, colored papers or colored models of the products to be graded. U. S. Standards for Grades of pecans and other nuts are available. While these methods are effective for routine inspection and grading, gross differences of opinion do occur as a result of subjective factors such as the spectral response of the individual's optical mechanisms, or because of physical factors such as fading or discoloration of the standards, or differences in ambient lighting conditions. Nonetheless, subjective comparison is an obvious improvement over purely subjective methods because the standard provides a reasonably stable reference.

Comparative Objective Measurements

Such measurements are made by an instrument which is designed to compare the spectral reflectance or transmittance of the sample with that of a standard. In general, the only errors in this type of system are those caused by individual inaccuracies of the optically active components and by spectral differences between similar standards. Unfortunately, the inaccuracies of the individual optical components are not necessarily minor. Very large spectral response differences have been noted between light sources, phototubes, and filters bearing the same model number and ostensibly conforming to the same general characteristic curves. Some spectrophotometers have a month-to-month reproductibility which is poorer than its short term duplication.

Purely Objective Measurements

Objective measurements pertain to instrumentation which does not rely on comparison with a colored sample and in which sources of error have either been obviated or substantially minimized. Ideally such an instrument should be electronically, rather than optically calibrated; and be designed such that the individual differences between similar components do not have an effect on the readout. In short, all instruments of a given type or model should read alike.

While the color measurement of homogenous materials is relatively easy, when attempts are made to control objectively or define the color of monhomogeneous and parti-colored products, several problems are encountered. Practically every tree nut, either raw or processed, had a statistical conglomerate of colors. The "monhomogeneous" nature is even more inclusive when extended to include such physical properties as size, geometry, and surface irregularities.

Few colorimeters and spectrophotometers are designed for quality control, and be suitable as such, they must meet the following criteria: (a) all similar instruments should read alike without need for constant calibration or mathematical correlation; (b) the instrument must be direct-reading in easily understood terms; (c) the instrument must withstand production area environments; (d) it must be easy to operate by semiskilled and even unskilled workers; and (e) the instrument must be reliable, requiring only infrequent cleaning and maintenance.

The Agtron instrument is suited to control color for raw materials or finished products—granules, paste, powder or liquid. Minute color variations are detected and color changes over a 100-point spread on a direct reading meter are projected. Thus, constant numerical values can be assigned to colors. The instrument is suitable for grading products of many consistencies such as kernels, pastes, crystals, purees and creams (Simmons 1966).

AUTOMATIC FILLING EQUIPMENT

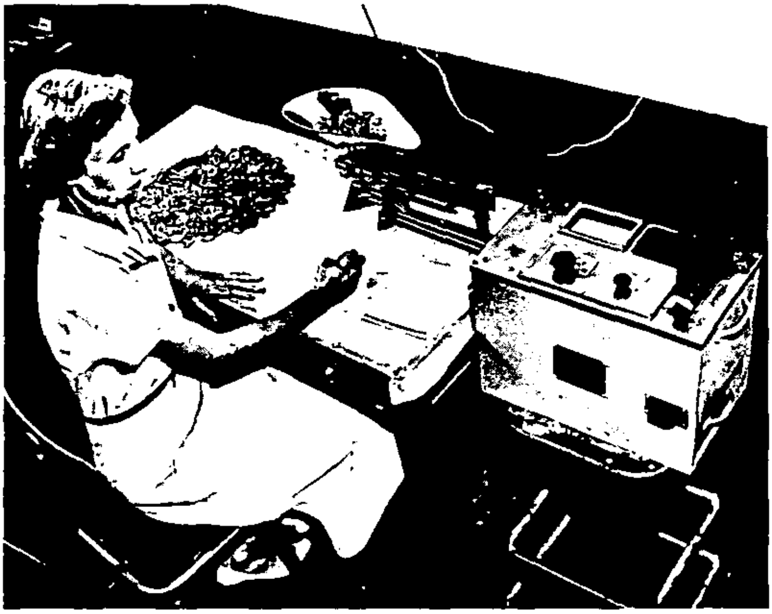
Much of the improvement in pecan processing has been in mechanical handling of the graded meats without hand labor. Following is a description of one type of filling machine. The twin discharge filler enables two operators to work filling two bags or containers simultaneously. The discharge spout and frame are designed for operation over and alongside conveyors, giving advantage of two fillers. The filler handles all semi- or free-flowing dry products.

The automatic rigid container filler with table top chain conveyor fills cans, bottles, tubes, jars, canisters, and other rigid containers with dry products such as nuts, candies or small bakery goods.

Food and Drug Administration officials keep a close watch on short weight packages. On the other hand food processors are concerned with overweight packages as this represents an almost imperceptible loss of great sums of money.

The American Sanitation Institute performs short weight checks either as part of their regular sanitation audits or on separate assignment. It recognizes the need in the food processing industry to protect the consumer from short weight and the processors themselves from overweight.

The Institute follows Food and Drug Administration procedures and uses the same Gurley balance. Fifty packages are weighed and the average weight is taken and compared with the label statement. In the event a package is short weight, the American Sanitation Institute's "unofficial" weight check allows the packer to correct the infraction before it is encountered and acted upon "officially." The short weight check program has three prime objectives: to help the client comply with the government's emphasis on full weight packages; to help save clients the considerable amount of money that might be slipping out in overweight packages; and to alert the client to any practices of "hidden" labeling of which they may be unwittingly guilty.



Courtesy Tracy-Luckey Co.

Fig. 130. Quality Is Controlled in Shelling Plant as the Weights, Grades and Moisture Content Are Recorded

VACUUM GASSING NUTMEATS

The equipment and process of packing nutmeats under inert gas may be described as follows (Jerissa Nut Company 1962):

The vacuum gassing process of canning has been developed to eliminate the action of oxygen on the product packed. Air, due to its oxygen content, is one of the most powerful agencies in the deterioration of food products. In as much as air contains oxygen, it is necessary to exhaust the air from the cans by means of a vacuum and then admit an inert gas, such as carbon dioxide or nitrogen. The use of gas, in addition to other benefits relieves the pressure on the can and prevents panels in the larger cans.

Two kinds of gasses may be used—carbon dioxide and nitrogen. These are tasteless, odorless, and inert gases. Nuts have a tendency to absorb carbon dioxide, and through this absorption a vacuum is created, strong enough to panel cans. Therefore, a high purity nitrogen is used for the packaging of nuts. To accomplish this method of packing, the air is withdrawn from the container by creating a vacuum in the chamber of the machine and subsequently filling the chamber with the high purity nitrogen at atmospheric pressure, or slightly above it, to prevent the infusion of air before the container is permanently sealed.

The machine consists of a 15 pocket rotary valve with a timed chain. On the chain are mounted doors with can carriers spaced in sequence to fit in the valve pockets. The chain and doors are operated by six stations of sprockets with an upper and lower sprocket at each station.

The cans are fed into a clinching machine, which feeds the covers automatically and clinches them to the can. The clinched cans are fed onto a transfer table, where the feed fingers transfer the can onto a can carrier. The can carrier, which is attached to the pivoted door, is now cammed to operate a little faster than the feedfinger, so that the finger does not hit the carrier. As the carrier takes control of the can, an outer guide centralizes the can on the carrier.

The can and carrier now enter the valve pocket, and at a predetermined point, the valve pocket is sealed by a spring operated finger until the vacuum seals the door to the valve.

The can is vacuumized in stages during the rotation of the valve to a point where the gassing cycle starts. At the end of the gassing cycle, the valve pocket is opened to the atmosphere. After the carrier leaves the valve pocket, the can is transferred to the closing machine infeed disc. The closing machine then premanently seals the cover. The vacuumizing and gassing valve government specifications require not nore than two per cent residual oxygen. The reason for this being that it was extremely difficult and costly to go below. With this new machine it is now possible to run at a constant of less than one per cent.

A few of the benefits of this type pack, are (1) that the nuts have a much longer shelf life, (2) retain their original color and flavor, and (3) have better stability after exposure to elements.

A vacuum bag-in-box gives shelf-life of 18 months to nut meats as compared to 6 months for canned nuts. The protection is in the bag that provides the vacuum. Its two layers of "alathon" polyethylene, one of polymer-coated "mylar" film and another of Alcoa's aluminum foil, hold a vacuum with less than one per cent residual oxygen. Mylar, as the outer ply provides the bag's strength. Joined to the 35-mil foil by a one-half mil laminate of alathon, it also completes a formidable gas barrier. A 2-1/2 mil extrusion coating of alathon serves to guard the foil liner from nut oils, acids or salts that might weaken it, and provides a "weld" when the vacuum is sealed.

Heat and pressure along the top edges of the filled and vacuumized pouch produce a solid seam of polyethylene. The vacuum immobilizes the nuts until the shield is broken, in this way splits are reduced.

The carton is strong and rigid for easy stacking, storing or shipping. A tear tape makes opening quick and easy. Since the packages do not rust, dent or shatter, are easily disposed of, and the nuts stay fresh longer, this package is especially suitable for export items. Furthermore, there is a saving on packaging cost of about five cents per consumer unit, as compared to tin or glass (Anon. 1966).

HOME CANNING NUTMEATS

Shelled nuts may be packed in tin cans and sterilized, in an effort to prolong the keeping qualities of the nuts. In the home, nutmeats may be heat processed in two ways. (A) They may be stored in sterilized jars from which the air has been exhausted. The jars are sterilized in boiling water, dried and filled with nutmeats of high quality. The lid is placed on the jar and it is partially sealed. It is then set in a container of hot water which comes to about two inches on the sides of the jar. After standing in boiling water for 30 minutes the jars are sealed, cooled, and stored in a cool, dry, dark place. (B) The jars of nutmeats may be sterilized with steam pressure.

The most satisfactory way to hold nutmeats is to dry to a normal temperature, pack in moisture proof containers and freeze. They may be held in this manner for more than three years.

SANITATION IN PROCESSING PLANT

Processing plants are faced with the ever-present problem of initiating economical sanitation program. The sanitary supervisor must have no other job priorities to prevent his carrying out essential functions. Insects present real problems in processing pecans.

A gas sterilizing facility for treating nutmeats with 100% propylene oxide or 100% ethylene oxide, at Union City, California, was completed in 1966 by Griffith Laboratories. A similar plant is in operation in Los Angeles and four are in foreign lands.

Fungus-resistant papers for packaging nuts (Mosinee Paper Mills) are designed to meet definite conditions of exposure to specific fungi. The papers are of various colors as well as white, and may be impregnated with different fungus-proofing materials. Some of them have odors which should be avoided for packing nuts. One paper is resistant to soil molds and another is resistant to cultures of *Aspergillus niger*, *Chaetomium globosum*, and *Aspergillus terreus*.

Use of Insect-Free Raw Pecans[1]

Nuts to be stored for a long period must be insect-free initially. The most common method of introducing an insect infestation into processed food is by using infested raw commodities. Although the processing will undoubtedly kill most of the insects present in the raw stock, a few may survive. One or two insects in a few packages is all that is needed to develop into a major insect problem. In addition, insects present in the raw stock spread through the plant and form a source for infesting the food as

[1]This section on "Protection of Nuts From Insect Damage" was prepared by H. Laudani, Entomologist, Stored-Product Insects Laboratory, U. S. Dept. of Agriculture, Savannah, Georgia (Laudani 1963).

is spread through the plant. Therefore, use only insect-free stock. If there is any indication that an insect infestation might be present, reject the commodity. If it must be accepted, fumigate it before it is brought into the plant. Use only approved fumigants, at the recommended doses.

Adequate Insect Control in Processing Plants

Insects can be introduced into the plant in many ways other than in the primary raw material. They may be present in blending stocks, in condiments, and in various supplies and packaging materials; or they may enter the plant from nearby sources. Constant vigilance for insect infestation in the plant and in the materials brought into the plant is a must. It is important, therefore, to have effective surveillance and sanitation programs to prevent insects from entering the plants, becoming established, and serving as a source for infesting the food during processing. Frequent inspection and cleaning of every part of the plant and every piece of machinery and equipment in the plant is important. Fumigate difficult-to-clean machinery and enclosed spaces. Use residual insecticides and space treatment where and when possible. Always strive to prevent an insect infestation from becoming established in the plant, and if one is discovered, clean it up immediately.

Use of Insect-Resistant Packages

Proper packaging is the most positive way of protecting processed foods against insect damage during shipment and storage. Pennies spent on insect-resistant packages pay larger dividends than dollars spent on insect control during shipment and storage.

The packaging material used greatly influences the protective value of a container by its natural resistance to insect penetration and its inherent suitability for forming an insect-tight container. Glass and sheet metal are the only food-packaging materials completely resistant to insect penetration. All others, such as paper, fiberboard, and foil, are subject to penetration by the cadelle, the lesser grain borer, and possibly by other stored product insects. The comparative resistance of the more commonly used pliable packaging materials, in order of decreasing resistance, are polyester film, aluminum foil, polyethylene film, cellophane, kraft paper, rayon sheeting, cotton sheeting, and burlap. The last three materials offer little or no resistance to insects. Within each of the other types of material, the resistance increases in proportion to the thickness of the film.

To overcome the inherent susceptibility of pliable packaging materials to insect penetration, a chemical treatment has been developed (Laudani and Davis 1955). A combination of pyrethrum and piperonyl butoxide applied at the rate of 5 mg. and 50 mg./sq. ft., respectively, will prevent insect penetration of multiwall paper bags for about nine months. The Food and

Drug Administration has approved this treatment and has established a temporary tolerance of 1 p.p.m. for pyrethrins and 10 p.p.m. for piperonyl butoxide in all foods packaged in treated multiwall paper bags.

The structural tightness of the package is as important as the packaging material used. The most resistant packaging material, whether natural or treated, is worthless if the container is not structurally insect-tight. The end closure of single-ply and multiwall paper bags should have pasted or heat-sealed tape-over-stitch closures. The insect-tightness of shell cartons is significantly improved by the use of well-sealed overwraps. Until better designed fiberboard shipping cases are made, complete taping of all joints is necessary (Laudani *et al.* 1958).

Of several hundred single and laminated films used for resistance to penetration by insects the most resistant is a single-ply polycarbonate type Lexan, supplied by General Electric Co. (Highland and Jay 1965).

Pyrethrum-piperonyl butoxide treatment on food packages has been accepted by U.S. Food and Drug Administration, when used on the outside layer of multiwall paper bags (Lehman 1956). In addition to synergized pyrethrum, methoxychlor, lindane, and synergized allethrin have been found promising. Pyrethum in combination with piperonyl butoxide applied as a clay coating at the rate of 5 and 50 mg./sq. ft. on the outer ply of multi-walled paper bags has been found effective in preventing insect infestation for 9 to 12 months (Laudani and Davis 1955).

Insect Prevention in Transport Facilities

Transport facilities are a common source of insect infestations. Freight cars are notoriously bad because of their construction and their multiple use. Surveys have shown that, during the summer season, as high as 96% of the freight cars are insect-infested (Wagner 1956). Grains and cereal products lodge in the walls of the car and become excellent breeding places for stored-product insects. Thorough cleaning of the cars eliminates some of the infestation, but insects in the walls are almost impossible to kill off, even with fumigation. Residual sprays help to kill the insects as they emerge, but care must be taken that these treatments do not contaminate the food. The walls and floor of the cars should be lined with heavy kraft paper after the residual spray has dried. Similar precautions should be taken with motor transport facilities. Clean them out thoroughly, spray all inside surfaces with a good residual insecticide, and then line the floor and walls with heavy kraft paper before the food is loaded.

Physical Requirements of the Warehouse

Successful protection of food against insect damage during storage requires a well-located, well-constructed storage facility, good warehouse practices, and the creation of an unfavorable environment for the insects.

Serious consideration should be given to locating the warehouse that is to be used for long-term storage of food. It should be as far away as possible from storage, handling, and processing facilities that deal with insect-infested materials. The surrounding area should be free of any potential insect source.

The warehouse should be well constructed. The building should be tight to keep out insects, rodents, and birds, and to keep in fumigant gases if such a treatment becomes necessary. The floors and walls should be solid and should have smooth surfaces. There should be no cracks, crevices, or dead-air spaces, which are difficult to clean and are excellent breeding places for insects.

Most stored-product insects prefer darkness or semi-darkness. A well-lighted warehouse will help discourage some insect activities. Good lighting is also essential for proper inspection of the premises and the stock.

Warehousing Practices

Stacking.—To protect nuts properly during long-term storage, good warehousing practices are essential. The warehousing practices used will have a direct influence on the effectiveness of the surveillance, sanitation, and insect preventive programs.

The nuts should be thoroughly inspected when they arrive at the warehouse. If infested, they should be rejected. If they must be accepted, then it should be fumigated before they are brought into the warehouse.

All food should be on pallets and arranged in neat stacks. Each stack should have a floor clearance of at least eight inches, cover no more than 1,000 sq. ft. of floor space, and be completely surrounded with aisles at least three feet wide. Food should never be stacked up against a wall. The four sides of every stack should be exposed and accessible at all times. Arrangement of the food in this manner (a) permits close inspection of a large percentage of the packages, (b) facilitates the repair or removal of broken packages, (c) permits more efficient rotation of the stock, (d) makes it easier to clean the premises, (e) increases the effectiveness of the insect-preventive program by better isolating small infestations, and (f) exposes the maximum number of packages to the insect-preventive treatments.

Sanitation.—Insects can develop, multiply, and survive on a relatively small amount of food. Spilled food and accumulated food dusts or sweepings can support heavy populations of stored-product insects. Good sanitation is, therefore, very important in preventing insect infestations in food warehouses. All surfaces should be kept clean at all times. This includes the open floor space as well as that under the pallets, on window sills, wall plates, and girders, etc. A heavy-duty industrial vacuum cleaner should be used for this purpose to keep the dust to a minimum.

Broken packages are an invitation to insects. Insects find such packages very readily. Once an infestation gets established, it spreads to other packages. Broken packages or spillings should never be allowed to remain on the premises. The packages should be repaired or removed immediately, and the spillings cleaned up.

Frequent inspections should be made of the food in storage to determine whether an insect infestation exists. This should involve a very careful inspection of the surface of the stacks and between the packages. The older stock should be sampled periodically. If an infestation is found, its seriousness and extent should be determined. If the insects are in only one bag or one lot, remove the infested stock immediately, and watch the remaining stock closely to see whether the infestation has spread. If the infestation extends over a large part of the stock, either fumigate the entire area or get rid of the stock as soon as possible. If fumigation is not possible, more frequent space treatments may be administered to keep the infestation from getting out of hand. No new shipments should be placed in a warehouse where a general insect infestation exists.

Insect Preventive Measures

In spite of every precaution, some insects will show up in warehouses where nuts are stored. It is necessary, therefore, to employ some means of preventing insects from reaching and infesting the food. This can be accomplished by using pesticides or by creating unsuitable climatic or atmospheric conditions.

Protection With Pesticides.—There are three distinct uses of pesticides for protecting stored foods against insect infestations: (a) the treatment of floor and wall surfaces with residual-type insecticides to kill crawling insects; (b) periodic treatment of the airspace with aerosol or mist formulations to kill flying and possibly some crawling insects; and (c) the fumigation of foods suspected of being infested.

Residual treatments.—The ideal residual treatment is toxic to a wide range of insects, is long-lasting, is compatible with the surface to which it is applied, and produces no undesirable effects on the food in storage or on the people working in the warehouse. No residual insecticide, whether of high or low toxicity, should be applied directly to stored food. Contamination of the food from "bounce-off" or drifting spray mist while floor and wall surfaces are treated should also be avoided. Equipment should be used that will produce a wet or coarse spray with a minimum of mist or "bounce-off." As a group, the chlorinated hydrocarbon insecticides have a longer residual life than the organic phosphates or carbomates. Residues of insecticides formulated as wettable powders generally last longer and resist chemical breakdwon from contact with alkaline or moist surfaces better than those applied as emulsions or oil solutions. Translocation of the insecticide from a treated surface to nearby food is a serious problem, which should be considered in selecting the insecticide to be used. The insecticide most commonly used for residual sprays in food warehouses is DDT.

Space treatments.—Space treatments are used to kill any insect that may be flying or crawling on an exposed surface. Such a treatment kills insects only while the insecticide is suspended in the air—and perhaps for a very short time on the horizontal surface on which the insecticide has settled. To be effective in insect prevention, therefore, space treatments must be repeated frequently. Because such a treatment comes in contact with the food or containers, the possibilities of contamination are great. The only pesticides approved and recommended for this use at present are the insecticide pyrethrum and the synergist piperonyl butoxide. Pyrethrins are used with piperonyl butoxide at the ratio of 1 to 10. The established tolerances on processed foods are 3 p.p.m. of pyrethrins and 20 p.p.m. of piperonyl butoxide. DDVP and other organic phosphate insecticides that have a very short life when exposed to the air look very promising for space treatment in food warehouses. DDVP must not be used for this purpose until the residue and tolerance status are established.

Fumigation.—Residual and space treatments are effective against insects that fly or crawl in exposed places. They have little or no value for controlling insects that are inside or between packages or in protected locations within the structure of the warehouse. If such an infestation had developed in a food warehouse, either the infested food should be removed immediately from the warehouse and the premises given a series of frequent space treatments, or the stacks of infested food and the surrounding areas should be fumigated.

Fumigants are dangerous to humans in the concentrations required to kill insects, and therefore, for the sake of effectiveness as well as safety, they should be applied only by experienced personnel. The fumigant should be selected carefully. It should be one that has been approved for, and is compatible with, all of the food and other materials present in the area under fumigation. The dose used and the number of times a single item is fumigated should be carefully controlled so that residue in the food will not exceed the estabished tolerance. A single fumigation with methyl bromide will leave on may nut products an inorganic bromide residue that is close to the allowable tolerance. Foods should not be subjected to repeated fumigation unless chemical analyses show that the accumulated residue will not exceed the tolerance. Methyl bromide and hydrogen cyanide have been approved for fumigating food, and tolerances have been established under the Food Additives Amendment.

Use of Unfavorable Environmental Conditions.—Insects require specific ranges of temperature, humidity, and air composition for development and survival. The creation of an unfavorable environment can be used very effectively for controlling or preventing insect infestations.

Cold storage.—Cold storage is an excellent example of the use of this principle. Generally speaking, temperatures of 70 to 90° F. are optimum for stored-product insects (Cotton 1960). Temperatures below or above this range have an adverse effect on the insects. At 60° to 70° F., the insects become sluggish and their development is very slow. Below 60° F., development practically stops. Freezing temperatures, if maintained long enough, will kill the insects. Although low temperatures can be used very effectively in protecting food against insects, temperatures in the range of 45° to 60° F. are ideal for many species of mites. These arthropods are smaller than insects, but they can be very damaging to many foods, such as cereals, dairy products, and dried fruits.

Most stored-product insects prefer high humidity and moisture, but they can get along very well at fairly low humidity, and many can feed on foods having a moisture content as low as 6 to 8%. Some can go even lower and provide their own moisture requirements by metabolic processes. The humidity-moisture factor, therefore, cannot be used as effectively as the temperature factor for control or prevention of stored-product insects, though it may be effective in preventing mite infestations.

Controlled atmosphere.—Stored-product insects cannot survive in an atmosphere that contains less than two per cent oxygen (Bailey 1955). By creating an atmosphere deficient in oxygen, food can be protected against insects. This principle has been used for many years in the storage of grain in airtight bins (Hyde and Oxley 1960). The respiration of the grain, insects, and fungi uses up the oxygen, producing carbon dioxide. When the oxygen falls below the two per cent level, the insects are killed off. A more recent use of this principle has been the exclusion of oxygen by drawing a vacuum or by flushing out the air with nitrogen as the food is packaged. Rather extensive use is also being made of controlled-atmoshpere storage for the quality maintenance of certain fruit (Schomer and Sainsbury 1957).

As nitrogen becomes more abundant commercially and cheaper to produce, it may find extensive use for protecting bulk and packaged food against insects. Equipment has been developed that is capable of supplying large quantities of nitrogen and carbon dioxide from butane gas. It may be possible that the use of controlled atmosphere will be more economical than cold storage, and safer and more effective than pesticides.

Chloronated and brominated wash waters (50–100 p.p.m.) are ineffective when treating a high bacterial count on belts and elevators. Quaternary ammonium salts could be helpful in cleaning washers and other equipment.

Methyl bromide treatment of stored nuts is effective. But its use is limited because of the 50 p.p.m. tolerance on inorganic bromide allowed. Propylene oxide treatment is effective but expensive. The use of propionates and sorbates, as biostatic agents, are being used.

Hydrogen cyanide has about 100 p.p.m. residue tolerance, when used as a fumigant.

Malathion and piperonyl butoxide with pyrethrins are permitted for use as "protectants." Tolerances are 3 p.p.m. and 1 p.p.m., respectively, for grains. Allethin has 2 p.p.m. tolerance on grains, and methoxychlor has 2 p.p.m. tolerance.

From an economic viewpoint insect infestation results in weight loss and reduces the grade. One processor "picked up" $16,000 worth of wormy cashew nuts which had escaped detection in the plant. It is desirable for nut handlers and processors to aim at complete insect eradication. Techniques have been developed for detecting internal insect infestation. Commonly employed are x-ray and flotation methods both of which require laboratory facilities. The x-ray method is faster, more objective and quite accurate. While less accurate, sieving and flotation methods are simple to use. They can be used in the shelling plant level to provide "yes or no" evaluation of infestation.

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Pecans in Bakery Products

INTRODUCTION

More than 26,000,000 lb. of pecan meats are used in an excess of 400 baked pecan products (Woodroof and Heaton 1961). Hess (1925) gave recipes for 302 bakery products containing pecans—159 cakes, 94 yeast breads, and 49 pies and pastries.

Approximately one-third of the pecan crop is used in more than a dozen bakery products. The quantity varies from year to year, depending on the price, quality and supply. The leading bakery products containing pecans are fruitcakes, custard pies, cookies, nut bread and cake fillings. Pecan halves are used for decorating cookies, cakes, and pies; pecan pieces are mixed into batters; and pecan granules, meal and butter are used to add flavor, consistency, and pleasing color to many products.

The number of pounds of pecans used by bakeries ranges from 150 lb. to 1,000,000 annually with the greatest percentage being in the 2,500 to 1,000,000 lb. category. Sweet rolls and fruitcakes are the main bakery products involved, with coffee cakes and regular cakes also ranking high. The use of pecans increased from 5% to 100% from 1963 to 1966, with the majority increase in the 5% to 25% area. Competitive nut usage ranges from 35 to 75,000 lb. annually, while 23% of bakers report the use of pecans only for nut-enriched products. The consumer appeal of the pecan products rated highest in practically every case.

What bakers want from shellers and processors is a universal grading system with standard names, sizes, colors and quality for pecans. Some bakers want pecan shipping containers labeled with the crop date and shelling date. More than 92% of the bakers indicated by a mail survey that they intended to introduce a new pecan product in 1967 (Bucklin 1966).

FRUITCAKES

Pecans are one of the major ingredients of fruitcakes. It is estimated that about 25% of the pecan crop is used in bakery products and that one-half of this quantity, or about 10,000,000 lb. of pecan meats, are used in fruitcakes.

Most bakeries make fruitcakes on a seasonal basis for Thanksgiving and Christmas holidays, but others make them the year round. One bakery in Georgia uses from 3,000 to 7,000 lb. of pecan meats per day for 4 or 5 months of the year and a smaller amount during the remaining months.