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Utilization of Some Farm Wastes

Chas A. Mann

Another group of researches has been concerned with auditory fusion where consecutive wave form varies. This follows the lead of Metfessel[12] who coined the term "sonance" to represent auditory qualities which depend upon variations of consecutive sound waves. Metfessel, nine years ago, pointed out that the vibrate in a singer's voice added a richness or liveliness to an otherwise constant pitch. Subsequently, Tiffin experimented to determine the nature of vibrate yielding various perceptual effects.

We know that the character of voice and instrumental sounds varies with the wave form and that training studies are now under way, under the direction of Seashore of Iowa, which set-up a standard wave form for the singer to produce, and that where the singer has finally reproduced the desired wave form, there is a desired quality in perception.

We have experimentally produced a pattern of sound waves each wave length or period of which has been slightly shorter and, in some cases the reverse, than the preceding one, thus producing what the singer knows as a slide. If such a pattern is of short duration, even with a range as great as two octaves, the observer reports a sound which has a more or less definite pitch located in the middle of the range but with a character wholly different from a tone of that perceived note. The human voice illustrates such patterns very well. Usually in the utterance of a single syllable, we phonate them in sliding fashion and unless the slide is pronounced both in range and duration the syllable by itself is rarely perceived as a definite slide but is allocated to a rather definite pitch on the musical scale, but with a character quite unique. We have begun researches in such patterns of a voice inflection to determine their various perceptual effects and, if possible, to set up standards in the training of speech since intonation is a part of language.

In this paper is presented evidence to support Seashore's dictum, that everything we hear is referable to the sound wave and that the pattern of configuration of the wave are series of waves, affords the basis for psychophysical studies in sound.

UTILIZATION OF SOME FARM WASTES

CHAS. A. MANN, PH.D.
University of Minnesota

In considering the utilization of any waste material for the manufacture of new products it is of importance to study some factors connected with the waste material as well as those of the products themselves. What are the possible uses of the products? What are the markets for them? Can they compete in price with others already available? Can entirely new uses and applications for them be found? Is it possible to make them in large enough

[12] *Psychol. Rev.*, 1926, 33, 459–466.

quantity? And as to the waste materials one must ask if there is a cheaper way of disposing of them than by processing them into something else? Is there a sufficient and regular or continuous supply or is the supply seasonal? What is the cost of gathering such waste material to a central place where it is to be processed? What will be the cost of a plant to convert these wastes and what will be the cost of processing because this, after all, will determine the sales price of the product as well as whether it can compete with similar products. So often the scientist and particularly the industrial chemist is criticized for not turning so many agricultural and industrial wastes and by-products into useful products. It is not because it cannot be done technically, but rather because of the question of economic and commercial feasibility.

The intention of this paper is to suggest the possible utilization of some farm wastes without regard to economic considerations. Some of these wastes are at present used commercially and with distinct success. The common direct farm wastes are the grain straws, corn-stalks, corn cobs, skim milk and in times of over production and low prices, the excess produce itself like the corn and the potatoes may be called waste. Some of the grains are so low grade that they may be considered waste because they bring a price which hardly pays for the cost of growing them. In addition the hulls of some grains, especially those of oats though not direct farm waste have become an important raw material for chemical manufacture.

Destructive distillation of vegetable matter like the straws, corn cobs and corn stalks as well as wood gives some interesting products. By destructive distillation is meant the breaking down of these complex materials by heating them to a high temperature out of contact with air. This is done in retorts or air-tight containers, heated externally. Four classes of products are obtained: Gases, pyroligneous acid, a watery liquid, tars, and charcoal. The amounts of the constituents and the characteristics of these are affected by the material used, the rate of heating, the final temperature reached, pressure and even the type of retort.

One ton of straw will produce about 10,000 cubic feet of gas, 151 gallons of pyroligneous acid, 10 gallons of tar and 640 pounds of charcoal. The gas has a heating value of about 300 B.T.U./cu. ft. It contains roughly 30% of carbon dioxide which is easily and cheaply removed, thus producing about 7,000 cu. ft. of gas per ton of straw of heating value 450 B. T. U.'s which makes a very satisfactory domestic and industrial fuel gas. The watery part of the destructive distillation contains acetone, methyl alcohol, acetic acid and allyl alcohol. Acetone was in great demand during the war for explosives manufacture and we sought to increase the amount obtained from the distillation of corn cobs which was actually done by heating the cobs with lime, though only 1.42% was the highest amount obtainable. At one time all of the acetone, methyl alcohol and acetic acid were obtained from the destructive distillation of wood and these products really were the money makers for the charcoal industry. Methanol and acetic acid are now produced synthetically and acetone is made from corn by fermentation, so that the pyroligneous acid, however obtained, is practically valueless.

Some important and desirable substances are found in straw tar. It has a high phenol coefficient and when properly fractionated by distillation supplies materials that can be used for sheep dip and for fly and insect sprays. The tar contains more than fifty different chemical substances some of which undoubtedly could be separated from the tar and uses found for them. It can be used for making roofing and building papers and for making paints and auto top dressing.

The charcoal or char resulting can be easily ground into a very fine powder and though somewhat grayish because of its high silica content (about 14%) it makes a good carbon for black paints. As the particles are in the form of platelets the paint film used for a priming coat on metals is very flexible so that repeated bending of the metal shows no craze marks in the film. The carbon can also be used in making automobile tires. For this purpose the silica or the poor black color should not be a detriment. Actual tests have proved its value for tire making. Instead of burning the straw which is commonly done and which leaves about 40 pounds of ashes per ton of straw some desirable industrial products can be obtained by destructive distillation. The ashes have no fertilizing value because they are mainly silica.

Straws have some value as paper making material but the expense and inconvenience of gathering them in the very large quantities required and the large amount of chemicals needed to make a high grade pulp prevents their competition with pulp woods. Attempts have been made to make straw briquettes for fuel purposes. All that is necessary is to compress the straw into briquette molds under considerable pressure. The heat developed causes a sticky tarry material to form which will hold the straw in the shape of the mold. These briquettes are hard and somewhat browned or charred, will ignite readily and will burn with considerable heat but unfortunately when they become heated or wet the briquette expands to a loose mass of straw. This is due to the softening of the tar or the solubility of the tar in water and because of the stiffness of the stalks the briquette opens or loosens up.

When straw is cut into smaller pieces and digested with about 5% cautic soda an adhesive is produced which will cement the partially converted straw into a loose and light board like material that has considerable heat insulating value but it is also a decided fire hazard. Such insulating board was made in Minnesota in 1909 from flax straw, though a board was made from the flax fibre as early as 1901. It is known as a semi-flexible straw insulating board and has found a number of important uses. Digestion with heat and with a more concentrated caustic actually pulps the straw. After draining off the excess liquor, the more or less plastic mass can be molded in various shapes. Pigments may be added to make it look like a clay product and when it has dried it becomes stiff and hard and retains its shape. It has been proposed to make shapes similar to clay roofing tiles. These would be light and therefore require a less heavy understructure to support them and at the same time be a fairly good insulator for the roof of a house. And they could be fastened to the boards of a roof by nailing them down. Unfortunately again the self contained adhesive made by the lye treatment is soluble in water. If these tiles could be made water proof they would be desirable and would be an outlet for straw wastes. There is also the possibility of aerating this straw pulp and blowing it into walls of buildings as an insulation material. To reduce the fire hazard it can be treated with a fire proofing material like zinc sulphate or ammonium fluoride or with some similar material.

One of the straws, that is flax straw, has found use in a special way. Flax is commonly grown for the seed from which the linseed oil is extracted. When the seed has a high oil content the linen fibre of the stalk is of inferior quality for textile purposes. After mechanical retting and with further treatment the fibers are used at present for making rugs. Such rugs are made by the Klearflax Company in Minnesota.

The shives obtained have a rather high content of pentosans from which furfural, an aldehyde, can be made. On a laboratory basis the shives will yield over sixteen per cent of furfural which has found a number of important uses industrially. It is claimed to have important insecticidal value. It is used by one large oil company to remove paraffine waxes from lubricating oils in refining the oil. It has been proposed to purify anthracene, a coal tar crude used in making the fast vat dyes by dissolving away the impurities from the crude anthracene. With phenols or carbolic acid a plastic or resin like bakelite, is made which has found extensive uses.

Furfural is obtained by digesting the shives with weak hydrochloric or sulphuric acid under pressure. When this digestion has been complete if the proper amount of phenol is added to the digested mass to make the resin and the whole thoroughly mixed and then further heated to drive off the water a liquid resin is actually produced which coats the particles of the shives. The hydrochloric acid present is desirable because it acts as a catalyst in forming the resin. Further heating gradually increases the viscosity of the resin and the mass becomes stiffer. It can now be molded into board or into other objects and with the application of pressure and increased temperature the whole becomes a hard solid. In the form of a board there are no knots, it will not check, it is water proof, resistant to most of the common chemicals and it can be sawed, cut, drilled and machined on a lathe. Moreover by introducing pigments any color can be obtained and by adding mineral filler any weight and resilience may be obtained. It should be useful for desk tops in chemical laboratories as well as for other purposes.

While discussing the manufacture of furfural it might be mentioned that any pentosan containing waste could be used. Some of these wastes like corn cobs and corn stalks give a lower amount of furfural than flax shives and others like oat hulls give a higher amount. Ten thousand pounds of furfural are produced daily from oat hulls at the Quaker Oats Plant at Cedar Rapids, Iowa, the only plant making furfural on a commercial basis. It seems strange that an industrial plant making a food product should make this rather unusual chemical, but it is because of the ever accumulating agricultural waste the oat hulls incur. Furfural furnishes a new source of income and provides a use for the hulls. The residue remaining is now dried and burned for its full value but new uses are being sought and investigated.

Corn stalks are difficult to dispose of except by burning or by turning them into the ground for fertilizer value, but they are an important raw material for a number of new products. The bast fibers of the corn stalk are from 0.4–5.6 mm. in length and 0.01 to .082 mm. thick and the cellulose content about 45% which would indicate that corn stalks should be a good paper making material. The stalks also contain about 28% pentosans probably xyloses and 31% lignin. In order to make a paper pulp it is necessary to remove the lignin and pentosans and other constituents of the stalks from the cellulose. This can be done by cooking the shredded stalks with caustic soda. The washed and bleached pulp, because of the fiber length can be made into paper which, however, is more or less translucent and stiff and looks much like parchment paper. It is necessary to mix this pulp with other pulps like sulphite or wood pulp to give to the paper the characteristics of a good grade of paper. Because of the high cost of collecting the stalks and of chemicals necessary for making the pulp as well as the manufacturing cost, this kind of paper cannot compete successfully in price with paper made from wood pulp.

Because of the fibrous character of the corn stalk it is an especially satisfactory material for making insulating board. In 1922 bagasse or spent sugar cane was used for making this kind of board. Naturally this suggested the use of corn stalks for this same purpose and in 1929 the manufacture of insulating board was started in Iowa as a result of the experimental work carried on at Iowa State College. The product is known as maizewood. There are three major operations used in making this kind of board: production of pulp, formation of mat and drying. Pulp may be produced by digestion with certain chemical solutions, with steam under pressure or by mechanical disintegration. When the shredded stalks are cooked with lime or caustic soda solutions at atmospheric pressure an unsatisfactory pulp results. Cooked with 2 or 3 per cent caustic under 40 lbs. pressure for 2 to 3 hours gives a good pulp, but the best pulp is obtained by the cooking process by heating with water alone at 40 pounds pressure for three hours. Increased pressure reduces the time of pulping. Other chemicals used in cooking methods are sodium carbonate, hydrochloric acid, nitric acid, and aluminum sulphates. Mechanical pulp is made by shredding the pulp with water in some form of shredder and particularly in a hammer mill.

All pulp must then be refined in which operation the fibers are separated and washed free of soluble material in a beating engine.

Matting of the fibers to form the board is difficult because of the physical characteristics of the fibers. To obtain a good board the fibers must be extremely well entangled so that the friction between fibers will hold the board intact. To improve the adherence between fibers, some sizing material which has adhesive value may be added which, depending on its waterproofing and fire proofing properties, will make a strong water proof and fire proof board. If not properly water proofed the finished board will absorb moisture which causes the fibers to loosen and to separate. Gypsum in the amount of ten per cent makes an excellent fire and water proofed board of good insulating value. If a hard board is desired it is necessary to apply pressure to the board before drying it, but in so doing the insulating value is likewise reduced.

In making such insulating board other wastes like straw, corn cobs, oat hulls, and peanut shells may be pulped with the stalks and incorporated into the mat. With over 500,000,000 square feet of insulating board of the rigid type used annually and a considerably greater potential market available it is entirely feasible to make board from cornstalks. The estimated amount of this raw material is 190,000,000 tons mainly concentrated in the north central part of the country.

The high content of pentosans in corn stalks makes them a suitable material for producing furfural, and the destructive distillation gives similar products and in similar quantity to those obtained from straw. Collection of stalks in the beginning was costly but the design of new machinery and carrying out the collection systematically has made the raw material cheap enough so that insulating board particularly can be manufactured cheaply enough to compete with other types of insulation. The board is especially desirable for insulating refrigerator cars, household refrigerators, and for house insulation. It can be made up to two and one-half inches in thickness. When properly made it can be painted and plaster can be applied directly and even without any coating it makes a fine appearance as a wall board.

Corn itself is of course used for making a number of industrial products such as corn starch, corn syrup, cerelose, a crystalline glucose sugar which is largely used by confectioners, bakers and brewers, corn oil, mazola, and the residues are converted into stock food. There still remains the leaves and the cobs both of which can be worked into the insulating board. Many products can, however, be made from the cobs besides pipes. In some localities the cobs are boiled in water and an extract is obtained which has the flavor of maple syrup. Mixed with cane sugar a synthetic maple syrup results. The cobs are used for smoking meats, as a fuel, and they have some slight value to improve the fertility of the soil.

By destructive distillation a charcoal is obtained which has good absorbent powers and is excellent for mixing in stock foods. This charcoal has excellent heating value, good enough to melt steel. Because of its low ash content it is valuable for reductions in chemical industries, where its further use might profitably be adopted. If it can be improved in its absorbing properties it might be used for air conditioning and for removal of odors and tastes from water. Finely ground it should make a good powdered fuel and as an extremely fine powder as a fuel for internal combustion engine.

When ground to about 10 to 20 mesh and freed from dust corn cobs can be made into a cork-like material by use of one of the modern plastics like bakelike, casein plastic or nitro-cellulose or cellulose acetate adhesives. The mass after pressing into shape is allowed to set. It can be made water proof and oil and grease proof either by the binder used or some other coating material. Much work is necessary to make board, pails, and other objects by this method, but this offers excellent possibilities. One particular value of this sort of synthetic material is that it is very light and resilient. It might be substituted for linoleum or floors could be made from it.

Inasmuch as the cobs contain a considerable amount of pentosans, it is possible by digestion with hydrochloric acid to produce furfural "in situ" then adding the requisite amount of phenol or carbolic acid and evaporating the water to obtain the binder like bakelite and the mass molded under pressure and at elevated temperature as desired.

Corn cobs are also susceptible to the action of caustic soda. When the ground cobs are heated with about 5 per cent of a solution of lye, the excess liquid removed, and the mass heated and put under very great pressure, a black board is obtained which is so hard and compact that it is difficult to machine or drill it. It can be given a good polish and it is fairly resistant to chemicals. Such a material should have some important uses.

Many chemical products can be made from corn cobs. The watery liquids obtained from the destructive distillation contain acetic acid, wood alcohol, and acetone, but the amounts are relatively small and costly to recover so that alone they could not compete with the synthetic products. Oxalic acid can be made by a nitric acid treatment or by a fusion method. The high pentosan content makes the cobs an excellent and easily workable source of the sugar xylose. On careful hydrolysis of either the cobs or the stalks the cellulose can be converted into glucose and the pentosans into xylose. After neutralization the former can be easily fermented to produce grain alcohol, but for high concentrations of alcohol the ferment is killed. Dr. Anderson working with Dr. Gortner of the University of Minnesota Biochemistry Department found a ferment that will produce alcohol from pentose sugars and which is resistant to alcohol. This might be used after the glucose has been exhausted and the fermentation continued on the xylose, thus making use of a large portion of the cobs for the production of alcohol. No comparison between the cost of making alcohol from corn cobs by this method and from molasses has been made, but there is the possibility of using the cobs or stalks as a raw material for obtaining alcohol. The constituents of corn cobs are also subject to other bacterial action. With a suitable bacterium producing carbon dioxide and causing the development of heat, the wet cobs can be used in place of tan bark in making white lead by the Dutch process. No doubt good fuel gas can be made by bacterial action on this raw material according to the proposal of Buswell of Illinois.

There may be many other uses for corn wastes but sufficient uses have been enumerated to indicate the possibilities.

When there is an over abundance of off grade grain, like wheat, which has little value for milling purposes or for feeding purposes it may be considered practically a farm waste. Can such grain be used for making some useful products? One suggestion is to convert it into activated carbon which is in demand for the purification of chemicals, as a refrigerator deodorant, in air conditioning and in water purification. Just how this can be done and whether or not a satisfactory product can be made are still problems. The grain can be carbonized by destructive distillation methods. Various methods are known for improving the absorbing qualities of carbons, but there is no information available as to the possibility of transforming grain to a high grade activated carbon. The requirements of a high grade carbon are well known so that experimental work can be directed toward making such a material. It seems desirable to make a puffed wheat by an explosion method first before carbonization to obtain the desirable physical properties of the carbon. No experimental work has been done on this problem to the author's knowledge.

Sometimes where there is overproduction of potatoes in certain localities this excess can be converted into alcohol or even potato starch, but this is not economically feasible at present. Beet residue from beet sugar manufacture is sold as a stock food. The residual liquors of beet sugar manufacture contain considerable amounts of potash that can be recovered when potash sells for a high price as during the last war.

Skim milk has some value as a feeding material. It is evaporated to a dry powder and this is incorporated in other types of stock feeds. The two important constituents of skim milk are casein and milk sugar. The first has become a very important material for the so-called casein products while the latter is used extensively in pharmaceutical preparations and in baby foods and in making beverages. A total of about 50,000,000 lbs. of casein is used for various purposes in the United States but half of this amount is imported. Only three states, California, Wisconsin and New York produce a high grade, usable casein in commercial quantities.

When both the casein and milk sugar are desired the skim milk is treated at about 35°C with hydrochloric acid of very definite strength. This is the most important commercial method of precipitation. The casein precipitates as a curd of such physical condition that is easily washable. After settling it is washed with a dilute solution of hydrochloric acid. It is then pressed to remove water and after spreading out on pans it is dried with heated air. To remove any adhering fatty materials it is best extracted with a volatile organic solvent. It is necessary to have a fat-free product for most industrial uses.

Casein is dispersed or partially dissolved in alkaline substances like lime, lye, borax, or water glass. To this can be added white or colored pigments and the mixture becomes the common cold water paint which forms a pleasant appearing surface. This paint surface cannot be washed but neither is the paint when dried easily rubbed off. Formaldehyde added to this paint makes it water proof and it can then be washed. Cold water paints are sold as dry powders, containing the casein, lime, pigment and paraldehyde or hexamethylene tetramine the latter two materials supplying the formaldehyde in dry form. This is thoroughly stirred into a definite amount of water and the paint is ready for use.

When the amount of casein is increased and a greater strength of alkaline solution is used so that the mixture becomes more viscous an excellent glue results, which is rapidly replacing animal glue and used by sash and door and furniture manufacturers. Formaldehyde makes this glue waterproof.

Because of this property of forming a coating material casein is used in the paper industry as a size, and to make enameled paper waterproof, grease and oil proof paper, emery paper, cardboard and the like.

When the dry powdered casein or even the moist curd is heated to somewhat above 100°C., it becomes very plastic and in this condition is can be kneaded, pressed, rolled or molded into any desired shape. When mixed with other substances like fillers or pigments these plastics dry and set to a non-inflammable mass which will not shrink. Such materials can be shaped in a lathe by cutting tools, can be ground and can be given a fine polish. Other materials like gums, waxes, or oxidized oils can be incorporated in the casein mixture so that different degrees of hardness, tensile strength, flexibility or resiliency can be attained. The product is odorless and tasteless. Such articles as buttons, buckles, beads, fountain pens, pencils, toilet articles, poker chips, dice, and billiard balls are made from this substance. This plastic material is sold under the name of karolith or galolith. It can be made to look like stone and when molded into slabs it is actually substituted for stone, particularly for interior decorative purposes. In many respects it is better than stone because it does not chip easily nor does it crack and it is easily fastened into place. Almost any kind of stone may be imitated.

The whey remaining after the removal of casein from the milk still contains the milk sugar which can be separated and converted into a marketable product.

High grade casein would find a ready market in the country. There is an abundance of skim milk available in the dairy states which could be diverted into the manufacture of casein which would bring in fine financial returns.

Many other wastes result from fruit orchards that might be converted into desirable and useful products. The citrous fruit growers found it worth while to manufacture citric acid, pectin, and essential oils from the cull fruit. Jerusalem artichokes may not be a farm waste but they are easily and cheaply grown and cultivated and might be an excellent means of income from farm operation. These artichokes contain large amounts of the sugar fructose which can be extracted. It is an important food, particularly for diabetics. Lack of familiarity with the products of different farms, and especially with the many varied waste materials coming from such farms, limits the consideration of other farm wastes. Moreover there are many more possible uses for these wastes than those discussed and which might suggest themselves.

As stated earlier this paper merely suggests the various possible uses of farm wastes. Research and further investigations alone will determine whether or not any one of these wastes can be utilized to make a process technically and economically feasible.

SCIENCE AND RUBBER TREES

E. C. STAKMAN, Ph. D.
University of Minnesota

It takes a flat tire to make many of us realize our dependence on rubber. What good is an automobile without tires, and what good are tires without rubber, and what good are we without automobiles? Much of our modern transportation is based on rubber, and tires are only one of the hundreds of uses to which it is put.

Until 1910 almost all of the world's supply of rubber came from Brazil. In the 16th Century explorers had brought to Europe a new substance, called "Caoutchouc" by the Indians of the Amazon Valley. It was interesting because it came from the milky juice of a forest tree, *Hevea brasiliensis*, and had unusual resilience. But it was not important until 1770 when Priestley found that it would rub out pencil marks. And so it was christened "rubber." The Indians had smeared it on wounds and on their feet as a protectant. And so Macintosh, a Scotchman, smeared it on cloth and invented the "mackintosh" in 1823. But in hot weather the coat got sticky and in cold weather it got stiff. Nevertheless, the use of rubber for waterproofing continued under this handicap until Goodyear in 1839 found that when crude rubber was treated with sulfur and