ON THE ABSENCE OF RESPIRATORY DISORDERS IN THOSE INHALING STARCH DUST OVER LONG PERIODS.

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It is generally conceded that there is no one circumstance associated with occupation which has a more baneful influence upon health than the protracted inhalation of dust.

The resulting morbid conditions of the respiratory tract which ensue are described under the generic heading "Pneumoconiosis," and contingent upon the class of "dust," the workers exposed to its inhalation exhibit lesions differing clinically in their course and intensity according to the *intrinsic* physical characteristics and specific chemical and physiological properties of the particular "dust." We must also bear in mind the factors which act *extrinsically* of the dust: what we may call occupation habits or concomitants, such as, for instance, intemperance, exposure, quality of ventilation, etc.

While these physical, chemical and physiological properties merge one into the other, and render the classification of dusts under these headings difficult, if not impossible, yet we may group them broadly as follows, in consideration of the immediate reactions between the inhaled particles and the tissues and fluids of the respiratory system. Along these lines we recognise:

1. *Insoluble dusts.*

   Organized: Hairy (wool), Fibrous (cotton, flax).

   Amorphous: Angular and sharp, becoming less so in the order stated:—

   1. Metallic, calcitic and siliceous particles.
   2. Coke and coal dust.
   3. Branny particles—(woody and siliceous).
   4. Woody particles—sawdusts, etc. etc.

2. *Soluble dusts:* Dusts originated by the grinding of:—

Nitrate of potash.
Carbonate of soda.
Caustic soda, etc.

3. *Dusts not directly soluble* as such, but becoming more or less so through the reaction with the tissues and body fluids.

(*a*) Starch granules, largely admixed with protein (12·0 per cent.), and cellular matters (0·3 per cent.), as commercial flour.

(*b*) Starch granules substantially freed from protein (0·4 per cent.), and cellular matters (0·05 per cent.), as commercial starch (maize).

The two last classes and a comparison of their effects afford the subject of this paper. In dealing with the former, reference will be made to the work of others, and comparisons sought with the data which I have been able to accumulate regarding the latter class, from observations extending for the last three years (since May, 1906).

Before entering "in medias res," it will be well, I think, to give a brief summary of the process of winning starch, and in so doing, to explain beforehand allusions I shall have to make to the workers in the various departments.

The grain (maize), after being soaked in sulphur water (dilute H_2SO_3) kept circulating through the "steeps" for about 72 hours at about 120° F. is cracked and degerminated, the germ separated and dealt with separately, while the endosperm and cortical portions are ground by millstones, and screened through "Silk" sieves. By this means the corn bran is separated from the crude starch liquors, which latter are rich in "gluten."

At an appropriate gravity (about 5° Beor sp. gr. 1·04) these crude liquors are run over the "tables," "gutters" or "runs"; which are channels about 120 feet long, 20 to 24 inches wide and 8 inches deep, made of concrete or asphalt, supported on an adjustable bed, and accurately kept level. By this means the glutinous and cellular particles are "tailed off," and the starch is deposited on the runs, from which it is shovelled off into "breakers." This process of "running" is repeated after an "alkali" treatment before it is manufactured into starch for culinary or textile purposes. A portion of the once run starch is "got up" in water, and appropriately hydrolized by acid for the manufacture of "glucose" in the glucose house-white. The tailings from the

silk sieves, i.e., bran, along with the glutinous tailings from the "runs," are dried in the Drying House, and sold separately, or admixed for cattle food.

The re-run starch is next put into "breakers"—tubs with strong stirring arms—, and "got up" with a minimum of water, then pumped to the "boxing houses." These are a series of perforated boxes about 6 feet long by 8 inches width and depth, standing over a trough for the collection of the drippings from them. The boxes are lined with cloths of unbleached cotton, and into these the starch is pumped, and allowed to drain "hard," after the manner in which curd is dried in the making of cream cheese. When hard the starch is broken into "lumps" and placed on trays to dry in steam-heated kilns. *Up to this point the starch being "wet starch," no dust arises from it.*

From this point, however, when the starch is dry, more or less dust rises during its handling for packing, according as it is packed in "lump," "crystal," or pulverized" form—in which last case it is ground in appropriate mills, and screened through bolting cloth. Such is the starch that is packed by the "Packing Room Girls," of whom more later.

As already noted, the resultant product consists of little beyond starch granules; proteins and cellular matters are present in but minute amounts. Upon becoming familiar with the environment of the workers in the packing and grinding departments during their working hours, it was borne in upon me that if anywhere, here must exist the circumstances which are sure to cause deleterious effects upon the health of the employees. Not only should the particles of starch on reaching the lungs set up mechanical irritation, but, despite the treatment of maize by "sulphur water" in the steeps, the starch prepared therefrom is far from being sterile. This allows of the probability of nocardiases in addition. The remarkable fact is that despite the abundant starchy dust pervading the rooms set apart for these departments my observations soon revealed to me a singular absence of respiratory disturbances among those working in these rooms. Further I found that during the fifty years during which these particular Starch Works have been in operation there had been the same absence of pulmonary disorders among the workers.

A study of the general appearance and demeanour of the starch workers while at their duties, and during their hours of leisure, forced me to the unwilling conclusion that they enjoyed unusually good health, and were perfectly contented with their environment, during the discharge of their duties. From enquiries made of the physicians who have practised here for periods of five and eight years respectively, my

conclusions appear to be in accordance with their experience in practice.

For lack of time due to other duties, I have been unable to make any systematic physical examination of the employees of the starch house, but of sixty-five of them whom I have questioned closely as to their health, not one was aware of any ill effects, or admitted to any pulmonary or respiratory trouble attributable to their occupation, but they all—more or less—admitted to constipation, which might, in part at least, with justice be referable to the sedentary, or may I say "static" conditions under which their work is performed. I shall refer again to this point. This fact is of paramount importance, for it is well known that common labour will "kick" for no good reason, and to all outward appearances, the starch befogged atmosphere which they respire, would seem to give them good cause for complaint. It is difficult to convey the extent to which the atmosphere of the (girls) packing room is pervaded by starch. I can only state that the average amount of starch dust which settles from the air at about twelve inches below the average nose line (the girls stand at their work) is 1·875 grains per square metre in twenty-four hours. Again, in the small filling room, which is really the dust supply to the packing room, the deposition of starch at the nose line reaches 4·120 grains per square metre in twenty-four hours. I may add that fully 95 % of this starch dust settles within the seven or eight hours of their occupation, and that it is heaviest in amount nearest to the filling room (near to which the guinea-pigs about to be mentioned are encaged), gradually abating as this point is receded from. In this filling room the one pound cartons of pulverized starch have been filled by the same man continuously for upwards of eight years. He makes no complaint regarding his health, but states that he was conscious of irritation from starch dust inhalation only during the first "two or three days, while new at the job." This is in accordance with an observation made on a guinea-pig. One was killed after living seven days in the packing room. Its lungs showed many recent (bright red) small broncho-pneumonic spots, sharply defined on the surfaces of both lungs, and which extended into the lung tissue. On section the lungs showed some bronchitis and a mild type of pneumonia, with some infiltration and the presence of large free cells in the alveoli of the type of the Staubzellen, or those of catarrhal inflammation. No starch granules were observed, even after staining with iodine, but it is fair to assume without a doubt, the broncho-pneumonic patches referred to above were caused by the irritation produced by inhaled starch granules,

even though so far, I have not been able to demonstrate them in the lung tissue. Three more guinea-pigs, exposed to the starch dust for one, two and three days respectively, and then killed, all showed a broncho-pneumonic condition in proportion to the periods of their exposure to the dust inhalation. Another animal was killed at the end of fourteen days within two hours of starch dust inhalations. The necropsy showed nothing, and on section, the lung presented an extremely modified picture of the foregoing observation. Five other test animals were killed at various intervals, extending to ten months of starch dust inhalations, and their lungs far from disclosing any lesion have been strictly normal in gross appearance and under the microscope. In all cases there was no persisting catarrhal inflammation of the upper respiratory tract, though in two cases a slight catarrhal condition was observed, and I may add that the very complicated nasal structure of these animals is not calculated to permit of the easy passage of starch particles into the ultimate elements of their respiratory tract.

To further satisfy myself as to the apparent good health, certainly amounting to an immunity from pulmonary troubles, enjoyed by the workers in the starch house, through the courtesy of the Chairman and Secretary of the Edwardsburg Relief Society, I was given an opportunity of looking into the distribution and disbursements of funds for the relief of the sick since 1906.

Following the enquiry yet one step farther, I tabulated the age, height and weight of workers in various departments, appending the number of years each has been working at his job. The object of this was to obtain some direct subjective evidence of any influence the dust inhalations might have upon the physical development of those exposed to it; though they may be personally unaware of it; as compared with workers in the same factory and locality, but pursuing occupations which excluded the element of starch dust inhalation. The average from each department is appended, as also are the percentage of attendances calculated from the possible working days.

In making the comparisons of "physique" as expressed in the appended tables, that accorded to the *wet starch workers* will be seen to be considerably higher than that of the workers in other departments. This is explained by the fact that this class of work, consisting as it does of shovelling wet starch from the "runs," and of working on the boxing houses, trucking and moving starch etc., is of a more arduous nature, and demands considerable strength in comparison with the output of energy to be expended by the workers in the other departments.

It is by no means a sedentary or "static" variety of work, and for that reason should be interpreted with reserve. Under the head of "Packing Room" all of the employees are girls, and due regard should be given this in the physique comparison. This then leaves only two "departments," viz. the Drying House and the Glucose House, to be compared with the dry starch workers, and shows no disadvantage to the last named, as the following table indicates. All of the starch handled in the Glucose House being *wet*, there is no starch dust therein, but in the Drying House it may be mentioned there is quite an appreciable dust from the dried bran, and especially from the dried gluten meal, which contains about 42 per cent. of starch, and 38 per cent. of maize protein. I have made no critical study of the conditions and of the workers therein, but they are apparently in good health, as is shown by the appended table.

Averages.

Department	Number employed	Age	Height	Weight	Years at occupation	Attendance percentage on possible working-days	Physique expressed in lbs. per year	Physique expressed in lbs. per inch	Physique percentages taking wet starch workers as 100 %
Packing Room (girls)	14	17·93	5·4$\frac{3}{4}$	119·86	2·16	97·6	6·68	1·85	79·5
Dry Starch ...	24	30·62	5·7	145·5	10·96	98·06	4·752	2·171	93·4
Wet Starch ...	27	30·96	5·8$\frac{1}{4}$	155·8	8·15	—	5·100	2·328	100
Drying house ...	16	42·75	5·7$\frac{3}{5}$	145·7	7·31	96·90	3·410	2·165	93·05
Glucose house ...	23	30·95	5·7$\frac{3}{5}$	146·56	8·65	96·73	4·740	2·1685	93·09

Withal however we have absolutely no evidence which could lead us to consider that the inhalation of starch dust under the existing conditions, even though largely admixed with (maize) "gluten" which has been dried thoroughly, at this plant at least, extending over periods of from one to forty years, and aggregating in all the departments, to as many as 829·6 years, has so far been deleterious to the health of those exposed to it.

On the other hand it is well known that a form of pulmonary disease suggesting tuberculosis and fibroid phthisis is not at all uncommon amongst millers, bakers and pastry-cooks. Among those who have reported cases of this kind are[1] Gerhardt. He called attention to the presence of starch in the expectoration of bakers, and to chronic disease of the lung, simulating tuberculosis, which had been excited by the inhalation of flour dust.

[1] Gerhardt (1896). *Centralblatt für innere Medizin*, No. 20.

Again, von Jaksch[1] has reported the case of a flour-mill hand in whose expectoration he found abundant starch granules which continued to be discharged after he had for two days placed the patient upon an absolutely starch free diet. The train of symptoms noted by him were similar to those depicted by Gerhardt, but with the superposition of a chronic nephritis.

It would seem from these observations that there are conditions in which starch taken into the lungs and upper respiratory tract is not immediately dissolved. Possibly this may be due to chronic inflammatory conditions set up by the irritation induced by the glutinous and cellular residues in wheat or such-like flour, which may enshroud the granules of starch, and so protect them for a longer or shorter time by the formation of an envelope relatively resistant to the action of the body juices.

I have examined 58 samples of sputum (collected after "coughing up," i.e., saliva and bronchial secretions) obtained from workers in the starch factory at different periods in relation to their exposure to starch dust inhalations:

(i) 18 samples taken as the workers were leaving the factory after a full day's exposure to the dust: in every case there was abundant evidence of starch dust.

(ii) 5 samples taken after 20 hours absence from the works: in every case maize starch granules were found embedded in the ropy post-pharyngeal and laryngeal mucous secretions. The granules were mostly the smallest in size.

(iii) 31 samples taken after about 36 hours absence from the works, i.e., on Monday morning—they being absent since Saturday afternoon. In 24 cases maize starch granules were found, but were extremely few in number, in 4 cases their presence was doubtful, while in 3, they were entirely absent.

In this series the samples were taken as they entered the factory gates before going to their duties. They were all dressed in their work-a-day clothes, much starch bedusted, and it is probable that in putting them on, they must have "raised a dust," and so most probably inhaled some of the starchy particles. This is substantiated by the fact that many of the larger sized granules were in evidence, in contradistinction with (ii) the "20 hour absence" tests; for these later samples were collected from individuals dressed in their Sunday best, and on their way from church, and showed the absence of the larger granules.

[1] von Jaksch (1906). *Verhandl. des XXIII. Kongresses für innere Medizin*, Munich.

It must not be lost sight of however that starch cells become wafted in the general atmosphere of the village, away from the immediate vicinity of the works, and that starch bedusted workers, on their way to and from work, will also disseminate the starch granules broadcast through the village.

In regard to the four doubtful cases I have no special remarks to offer, but in the three cases in which no starch cells could be found, I afterwards learnt that two of the individuals were in the habit of changing their starch-dusted working clothes before leaving the factory, and this was doubtless contributory to the absence of starch grains in their sputum. Two more cases, absent from the factory for three days, showed very slight numbers of starch granules, but they were garbed in dusty clothes, and the granules seen were both large and small.

The last case, an individual one, and one of the men employed in grinding the starch, was away from the village for four days. The sample of sputum was taken as soon as he disembarked from the train; no starch was found therein. I may mention that in nearly all of the samples taken from the workers as they entered the factory gates on Monday morning, wheat starch—from the bread of their morning repast—was encountered, and where "starch" is unqualified above, reference is made to maize starch.

The general indication obtained throughout these microscopic examinations was that the smallest sized starch granules persisted longest in the sputum; they all stained intensely blue-black. In some cases, where the larger granules were seen, a few appeared more or less eroded, and did not stain so deeply with iodine. The general indication is that there appears to be some difference in the molecular constitution (if not composition) of the smallest and largest starch granules.

It might be mentioned that this investigation was done in the works' laboratory. By ordinary methods of washing and wiping of slides, it was found impossible to get them free from starch. Even the iodine solution in a ground glass stoppered bottle (in which it had been standing several weeks) was not starch free. It was found necessary to boil the iodine solution in order to destroy the contained starch cells, and also to keep all slides immersed in boiling water up to the time of using.

Several "blank" observations were made during the examinations reported above, so as to satisfy myself that all samples were examined under "starch free" conditions.

I must now refer to three dry starch workers—men—who do not

enjoy good health. They were ailing before taking up their present occupation. They are not aware of having become more ill since, but they are sure that their environment is not conducive to their well-being.

Case 1. Age 52. Had been a labourer on railway construction until three years ago, and left that occupation on account of failing health, and has worked ever since then in the starch house. Complains of pains in small of back and in groin, at times becoming very acute, and there is occasional distress on micturition. I would surmise, from what he tells me, that he suffers from "gravel."

Case 2. Age 32. Has never been robust, and for last eight years has been working in the starch house. Suffers from a chronic catarrhal condition of the throat. He is of a nervous temperament, and sleeps badly, awakening with a smothered feeling. Has never been troubled with a cough or other respiratory discomfort, except that above alluded to. Since he has taken more out-door exercise, and has been more careful with his diet (suffers from starch indigestion) he sleeps better, and the vicious train of symptoms is disappearing.

Case 3. Age 35. Has worked in the starch house for years although a victim to asthma. Drinks to excess—is in a very depressed state of vitality.

I have had no time to examine more fully into these cases, but I shall do so in the near future, when an opportunity offers.

To sum up briefly, from the foregoing it is evident that while protracted inhalations of *flour dust* induce morbid changes in the respiratory system, those of starch granules (maize) practically in a pure state appear to exert no such adverse influence *per se*. However, in cases where an illness is not completely recovered from, a depression of vitality is maintained, and other intercurrent diseases may supervene as a result. The reason for this is strongly indicative that flour dust, on account of its glutinous content, and the *nature* of the gluten, forms an intractable dough with the body juices, and is converted into a mass which, not being amenable to lysis, remains behind, and becoming a "foreign body," sets up irritation of the parts. On the other hand, *starch granules per se, as in relatively pure maize starch granules,* or even admixed with a very large preponderance of maize "gluten," not tending to form a dough, are easily of access to, and are rapidly removed by, some agency, and are not given the opportunity to become a foreign body, and to set up irritation.

Though the empirical chemical composition of all *starches* is identical, a few of the striking differences in chemical and physical characteristics of these two classes may be gleaned from the following:

Flour dust	Maize starch dust	Gluten meal dust
1. A high protein and cellular tissue content: the protein forming a sticky, doughy mass, with moisture.	A low protein and cellular tissue content.	A high protein, starch and cellular tissue content: the protein, however, not tending to form a dough with moisture, and the dried protein being hard and brittle, and resembling to some extent hardwood sawdust.
2. Circular and oval granules, varying in diameter from ·005 to ·041 mm.	Faceted polygonal granules roughly hexagonal, varying in diameter from ·007 to ·023 mm.	
3. In boiling water forms a milky and relatively mobile paste, thickening up rapidly on cooling, with formation of flocculi.	In boiling water forms a relatively translucent and cloggy paste, thickening up more slowly and with less marked flocculation.	

Without going farther into these chemico-physical differences, let us turn our attention to the mechanism by which the starch granules are removed, after gaining entrance to the lower respiratory passages.

It is well known that the blood contains an amylolytic enzyme which, according to Halliburton[1], is said to convert starch into iso-maltose,—and incidentally I may mention the entity of iso-maltose is, to my mind, somewhat undefined, and savours of a malto-dextrin, or of "gallisin"? This diastatic enzyme in the blood has been shown to increase during constipation and to decrease during diarrhoea, and is held to have its origin from the pancreas. I have mentioned previously the fact that the dry starch workers complain of constipation, and I am told by the two practitioners here, and by one in Prescott, that they have had cases of dyspepsia from amongst them which have shown marked inability to digest starchy foods. Is this constipation *due* to a call for an amylase in the blood to digest the inhaled starch? By so deflecting that pancreatic enzyme from its normal channel, is "starch indigestion" caused, and constipation engendered by an induced quiescence of the bowel? The inhaled starch, if digested by an amylase in the blood,—is it utilized by the organism, or is it voided through the urine before its oxidation is complete? I have examined upwards of fifteen samples of urine from different individuals, and have invariably found the specific gravity, colour, odour and reaction to litmus and lacmoid papers normal. No trace of sugar, acetone, or diacetic acid has been found in any one of them, but they all without exception

[1] Halliburton, *Essentials of Chemical Physiology*, 4th Edition, p. 141.

show up indican in smaller or larger amounts, indicating thereby lack of normal intestinal activity and tone.

Anent the inhalation of starch dust, Parkes and Kenwood, in their *Practical Hygiene*, 3rd edition, p. 185, state: "Millers and bakers are liable to inhale flour dust, but as this substance is probably arrested in the mouth and nose, and does not reach the lungs, it can hardly be regarded as productive of lung disease." Because of the very excessive quantities of dust to which such workers (starch packers included) are exposed, is the flour or starch dust not liable, so to say, to form an incrustation over the tubulure of the upper respiratory system, which will present a fairly "*dry*" surface, incapable of collecting after a while, any more flour or starch dust, and so eventually allowing these particles to reach the alveoli? Though starch granules have not been demonstrated in the guinea-pigs' lungs in the four tests made, a broncho-pneumonia has supervened. Some of the hands tell me that the starch "*dries up*" *their saliva and bronchial secretions*, and that they cough up lumps of slime with starch four and five days after being away from the factory. A few have also told me that for relatively long periods after they have been away from the works, starch seems to "come from the pores of their skin." These matters I hope to be able to investigate during our four week midsummer shut down.

Moscati of Naples[1] has observed the destruction of starch pastes injected intravenously and subcutaneously into the organism, and suggests the probability of glycogen being formed from the starch so injected. This idea of anabolism, or rather for the want of better terms, I should say "anabolic Katamerism," or depolimerization of starch (pastes) into glycogen I cannot support. It appears to be heterodox to expect that the organism should *reorganise and store for future use a body unnaturally and a-topically "invading" it, and hence a foreign body, when its every effort should be, in the light of our present thought, to break it down, to simplify and to annihilate it and throw it out.* He does not seem to take into account the degradation of the starch pastes through the "amylo-" and "erythro"-dextrins into its final reducing sugar, and the fact that at a period in a diastatic starch conversion, the classical mahogany-purple-brown iodine reaction of glycogen is arrived at, (at about [α]) and may be misleading under certain conditions, and especially in the presence of proteids. However, he conclusively shows that the organism is endowed, not only in its blood, but in its various

[1] *Zeitschrift f. Physiol. Chemie*, vol. L. p. 73.

organs and tissues, (possibly through the blood serum therein) with an abundant normal amylolytic power.

He does not suggest the probability of the exaltation of the amylolytic power of the organism to combat (as an anti-body) the invasion of starch. To establish or disprove this has been the cardinal idea of the investigations made through the courtesy of Professor Adami in his laboratories by Dr A. C. Rankin, and by myself here in the laboratories of the Edwardsburg Starch Company. The results of these experiments were conflicting, though interesting, and our data do not allow any definite statement on this point to be made in this paper, nor have we enquired into the nature of the final sugar produced. Parallel series of blood examinations for amylolytic power were conducted on men, rabbits and guinea-pigs, which on the one hand had been subjected to the inhalation of starch granules, or injections of starch pastes, and upon the other, those which were not so exposed. But in our controls, such large variations were noted among different individuals, and even in the same individual at different times, as to render the information obtained useless for the establishing of a "normal." Similar results were noted in the experiments, though upon two occasions it seemed as though a distinctly great exaltation in amylolytic power was observed as being due to the exhibition of starch. An explanation of these irregular results may reasonably be sought in the relative importance of the digestive ferments to animals of differing proclivities in regard to their diet. For instance, if we grant that the enzymic activity of the blood and other body fluids is the expression of the degree of diffusion or seepage into it from the glands properly detailed to secrete these ferments, then in the blood of herbivora and graminivora (guinea-pigs, rabbits etc.) we should find a high normal amylolytic, and correspondingly low proteolytic power. In omnivora (man etc.) we should expect to find a relatively smaller amylolytic, but higher proteolytic power of the blood, while in carnivora we should reach the other extreme, and therefore find that their blood serum was rich in proteolytic ferments, but low in amylolytic. These are matters which require further investigation.

In a letter (Feb. 12th, 1908) I wrote to Prof. Adami telling him of my views regarding the probability of an exaltation in the amylolytic powers in the blood of those who are exposed to starch dust inhalations, I mentioned the fact—which was corroborated by our local practitioners —that while there were several cases of malignant new growths (both carcinoma and sarcoma) in our village, it was remarkable that no case of malignant disease had ever been observed in persons employed amongst

starch dust, though cases had been known to exist amongst the out-of-door group. Upon purely casuistic grounds I discussed the matter from the standpoint of Beard's trypsin treatment for cancer.

About eight months later, while working independently, Dr A. A. Bruère of the Clinical laboratory of the Royal Victoria Hospital, I am told by Dr Adami, found an exceptionally well marked amylolytic activity of blood drawn from a patient then diagnosed to be suffering from a mediastinal lympho-sarcoma. The diagnosis was confirmed at autopsy.

I am grateful to Professor Adami for the interest he has taken in my ideas, for his kind direction, and for the many facilities accorded me; to Dr A. C. Rankin I am also greatly indebted, for much unselfish work done on my behalf. Lastly, I must thank Mr G. F. Benson, President of the Edwardsburg Starch Company, for the unhampered facilities allowed me in obtaining data, and for the use of the excellent laboratories of the Company at Cardinal.