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Effect of Feed Concentration on the Production of Pregelatinized Starch in a Double Drum Dryer

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Abstract

Double drum dryer is operated for producing pregelatinized maize starches using feed starch slurries of different solids(7, 10 and13 g/100 g)content . Steam pressure (2,3,and 4 bar), the level of pool between the drums (4,7,and 10 cm) , and speed of drums rotation (3,4,and 6 rpm) are varied together with the feed solids content in a practical range of values. The response of the dryer is registered by measuring several output variables, i.e. external drum temperature, product moisture content, mass flow rate.

***Keywords*:** drum drying, pregelatinized starch, feed solids content.

Introduction

The use of drum dryers is a common industrial practice for the production of a variety of foodstuffs such as yeast creams, fruit purees, baby foods, mashed potatoes, dry soup mixtures, pregelatinized starches, [1].

Pregelatinized starches simply pre-cooked and dried are starches that readily dispersed in cold water to form stable pastes and are used mainly as thickeners in foods and as adhesives in the textile industry [2].

The boiling type of drying involved in drum drying makes pregelatinized starches be indeed very porous and easy to rehydrate, ready to use [3,4].

Drum –drying results in specific physicochemical modification of the native starch due to the gelatinization and further solubilizatioin of the starch granules .The delivered products often referred to as pregelatinezed or instant starches are customarily in the form of thin solid sheets. These starches prepared in two consecutive stages : complete gelatinzation (to improve the nutritional value of starch) and drying. Both stages exploit the heat transferred from the surface of the steam-heated drums to the wet product.

A double drum dryer consists of two counter rotating horizontal cylinders of equal diameters, Fig. 1. The cylinders are hollow and are heated by steam condensing on their inside surface. One of the cylinders can be usually adjusted at right angles to its axis so that the gap between the two drums may be varied. The starch suspension is fed into the wedge-shaped space formed between the two drums (pool) where it heats up and gelatinizes. The gelatinized starch is calendared into a thin layer as it passes through the gap forced by the rotary action of the closely spaced drums. Right after the gap this layer splits into two films of gelatinized material, one for each drum. These films progressively dry as they rotate being adhered to the drums and are finally scraped off by blades extending the whole length of the drums. Thus, drum dryers are essentially conduction dryers, the drying effect being obtained by the transfer of heat from the condensing steam through the metallic body of the cylinders to the film of the material covering the external surface of the drums.

A survey of the recent literature shows that studies dealing with double drum dryers are rather scarce and are mainly of technological orientation. e.g. [5].

It is recognized that the presence of two drums in double drum dryers dictates quite distinct operational characteristics and direct comparisons with single drum dryers are not possible. For instance, in single drum dryers mass flow rate and film thickness depend very little on steam pressure since the gap is chiefly determined by the adjustment of auxiliary rollers Conversely, in double drum dryers steam pressure Is a major parameter influencing gap width [3]

There are four input variables involved in the operation of a double drum dryer for a fixed feed material: (a) steam pressure, (b) speed of drum rotation, (c) pool level between the drums and (d) condition of the feed material, i.e. concentration physical characteristics and temperature at which the material reaches the drum surface.

The temperature around the inside surface of the drum is quite constant but always less than the temperature of the supplied steam. On the other hand the temperature at the outside surface of the drums is not constant and is a result of a combination of all operating conditions [5]..

The purpose of this work is to investigate the effect of the different conditions of the feed material. Among them, special attention is paid to the role of the solids content of the feed slurry on the performance of the drum dryer. For this, the interaction among all input variables and their relation with certain output variables of the dryer (product moisture, mass flow rate) is examined.

Materials and Methods

Commercial native maize starch is purchased form al-Hashimya factory, with moisture content of 13.5 g/100 g. The total amylose content is 13.5g/100 g.

Native maize starch is modified by a double drum dryer (Trocknungs Anlagen). The drums have 0.3m diameter and 0.3m length and are synchronously driven at 2, 3 or 4 rpm The drums are internally heated by steam at 7, 10 and13 g/100 g. The level of the free surface of the liquid pool between the two cylinders is regulated (manually) at 4, 7, or 10 cm above the gap. Starch/water suspensions with solids concentration of 7, 10 and13 g/100 g (wet basis) are employed as the dryer feed This range of concentrations is selected in order to get good-quality products given the range of the other input variables of the dryer.. The feed suspensions are prepared in a continuously agitated large tank (5 L) where from a rotary positive displacement pump drives them to the dryer. A uniform distribution of the starch feed over the whole pool area between the drums is achieved by letting the suspension pass through a perforated horizontal tube, running the length of the drums, and free fall into the space between the drums. The feeding of the dryer is done only after the drums have reached their final stable temperature After traveling 3/5 of a revolution, the dried product is removed in the form of thin sheets by the blades Samples of the dry product are collected with the dryer operating at steady state. Each experiment includes at least three measurements at every particular set, Moisture content of the product sheets is determined by using the loss-in-weight technique. Mass flow rate is measured by collecting and timing large amounts of product sheets as they come off the drums.

Results and Discussion

Evaporation losses from the pool decrease substantially as the solids content of the slurry increases. It appears that the other (than the feed concentration) operating conditions of the dryer do not seriously affect the evaporation losses from the pool. For all the examined concentrations, at higher pool levels the free surface of the pool appears less disturbed by the boiling activity.

The dry product sheets that are scraped off by the doctor knifes ,it is observed that feed slurries with higher solids content result in thicker and more humid products. For a 13 g/100 g slurry sometimes wetter zones appear randomly here and there on the product sheets. In all end products the granular shape of starch is completely absent. Instead, the sheets look like a composite medium in which irregular air pockets are randomly distributed inside the continuous solid phase.

Effect of steam pressure vs. feed concentration

In order to study the influence of the parameters on drum operation a reference local temperature is chosen; the one measured on the bare metallic surface of the drums just after the doctor blades. The same location was also chosen by[5], who observed that temperatures measured at this spot fluctuate less with time than temperatures obtained at other locations around the drums where the material is present.

Steam pressure has a direct influence on drum temperature Increasing the steam pressure increases the inner and, consequently, the outer temperature of the drums.

This effect is clearly seen from Fig. 2 where runs conducted with a pool level of 7 cm and a speed of4 rpm are presented. Clearly, the highest temperatures are observed for the more concentrated slurries. Fig. 3 displays the variation of product moisture with steam pressure. Increasing the steam pressure generally makes the moisture to decrease unless it is already low enough (7 g/100 g slurry). Furthermore, the more the solids in the feed slurry the more the final product. Fig. 4 shows the dependence of the total mass flow rate on steam pressure.

The higher drum temperatures for the more concentrated slurries in Fig. 2 (for fixed steam pressure) manifest a poorer external heat flux (drum-material). The fairly constant internal heat flux provided by the condensing steam inside the drums is only partly received by the material outside the drums, the other part is being used to rise the temperature of the drums which act as heat reservoirs. In this respect, two distinct contributions can be identified. One refers to the external heat flux from the drums to the material gelatinizing in the pool and the other to the material drying as a thin film after the gap. As regards the pool material, a reduction in heat flux might be expected due to the increased viscoelasticity of slurries with higher solids content which not only retards convective currents in the pool but also hinders the removal of vapor bubble screated by boiling on the drum surface. Regarding film drying over the drums, at least three parameters must be taken into account: the transport properties, water activity and thickness of the material. A more moist starch gel has higher heat conductivity and moisture diffusivity. However, both properties are strongly related to the temperature and texture of the material. In particular, the role played by the progressively increasing porosity (void fraction) of the drying gel is a higher porosity means lower heat conduction but higher mass diffusion. This is so because air has lower heat conductivity than any liquid or solid but moisture transfer by vapor diffusion is much faster than by liquid/ solid diffusion

At first glance Fig. 2,3, and-4 implies that the lower production rate as steam pressure increases for feed concentrations of 10 and 13 g/100 g may be due to the higher temperature of the drums which can remove more moisture from the product. One must realize, however, that the temperatures in Fig. 2 are indicative of the overall thermal condition of the drums . Thus, a higher drum temperature corresponds to a narrower gap between the drums which can result in a smaller throughput rate.

Effect of pool level vs. feed concentration

The level of the pool dictates both the volume of the slurry in the pool and also the contact area of the slurry with the drums, so it is directly associated with the heat delivered by the drums. The pool level also determines the residence time of the material in the pool, which dictates the degree of starch gelatinization and therefore the viscosity of the slurry . Fig. 5 presents the effect of pool level on drum temperature. These tests are performed with a steam pressure of 3 bar and a drum speed of 4 rpm. Generally, the temperature drops as the pool level goes up . This may be attributed to a higher boiling load with pool level: the temperature of the drums fall because of a higher heat flux from the wall towards the material. However, the higher temperatures observed in Fig. 5 with the more concentrated slurries (for the same level) indicate that the transport properties of the material also influence the external heat flux of the drums. Thus, for a more concentrated slurry the ability to convect and conduct heat from the outside surface of the drums to the material is deteriorated and so the temperature of the drums rises given the finite heat capacity of the drum walls.

Figure 6, and 7 displays the variation of product moisture, mass flow rate with pool level for the same runs as in Fig. 5. Moisture is not seriously affected by pool level for concentrations of 7 and10 g/100 g. In this case, it appears that the thermal capacity of the dryer is high enough regardless of the other parameters so as to permit comparable drying of the material. This is different for a 13 g/100 g slurry where the moisture cannot be adequately removed when the pool level increases but an increasing trend is observed with pool level. Inspection of Fig. 7 indicates that the flow rate and film thickness may only be partly blamed for this.

From a practical point of view, at low pool levels, variations in feed concentration influence less the performance of the dryer. Vice versa, operation with a feed concentration of 7 g/100 g is less sensitive to variations of pool level. It is also interesting that for a 10 g/100 g slurry rising the pool level to 13cm results in higher production rates with a virtually constant moisture

Effect of drum speed vs. feed concentration

As the speed of rotation ascends the drum temperature descends, Fig 8. The presented tests are conducted with a steam pressure of 3 bar and a pool level of 7 cm. The figure shows that , as throughput rate increases more heat is delivered by the drums where as thinner films result in higher heat fluxes, too. In addition, shorter drying periods (higher rpm) are associated with lower drum temperatures since there is not enough time for heat build-up in the drum walls. In Fig. 9 the influence of drum rotation speed on the moisture of the final product is shown. A higher rotation speed generally causes wetter end products. It must be added though that the lower the feed concentration the smaller the influence of speed while at a concentration of 7 g/100 g practically no influence is observed because the material is too dry even for a 4 rpm speed. Fig. 10 displays the variation of mass flow rate with rotation speed. Here the dominance of concentration against speed of rotation is prominent. So for the higher feed concentrations(10 and 13 g/100 g) the present results show that the product outflow increases with speed.. The respective film thickness is essentially invariant among the examined rotation speeds (considering the statistical significance of the determination).

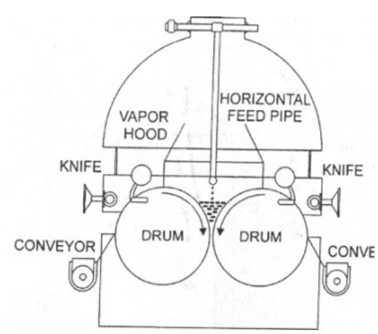

Fig. (1) : Schematic representation of the employed double drum drier (Trocknungs Anlagen).

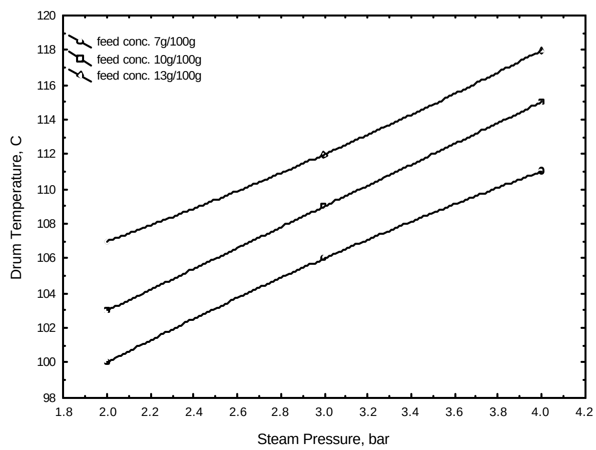

Fig (2): Effect of steam pressure versus feed concentration on drum temperature, other experimental conditions pool level 7cm, drum speed 4rpm.

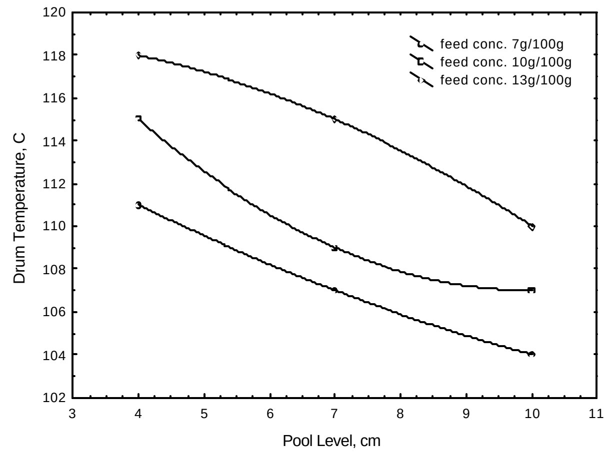

Fig (5): Effect of pool level versus feed concentration on drum temperature, other experimental conditions steam pressure 3bar, drum speed 4rpm.

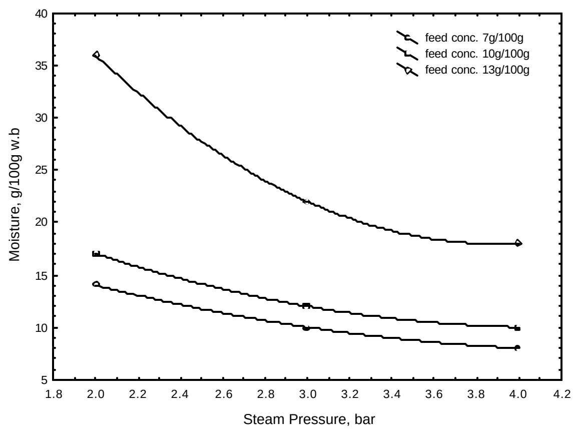

Fig (3): Effect of steam pressure versus feed concentration on product moisture content, other experimental conditions pool level 7cm, drum speed 4rpm.

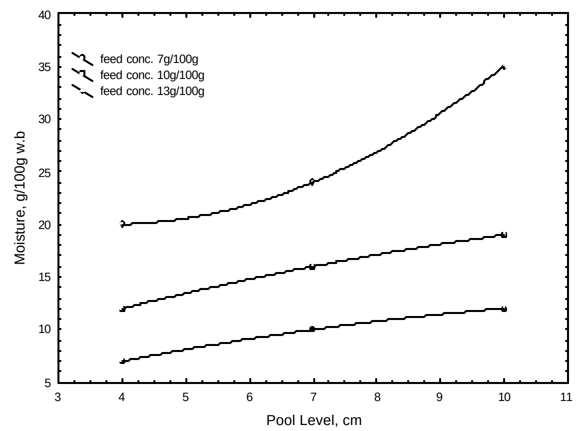

Fig (6): Effect of pool level versus feed concentration on product moisture, other experimental conditions steam pressure 3bar, drum speed 4rpm.

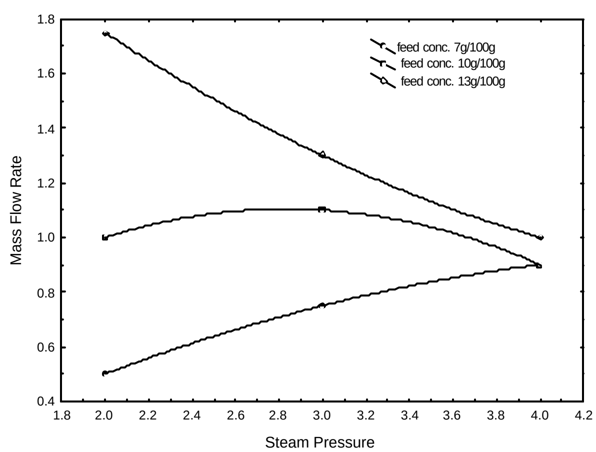

Fig (4): Effect of steam pressure versus feed concentration on mass flow rate, other experimental conditions pool level 7cm, drum speed 4rpm.

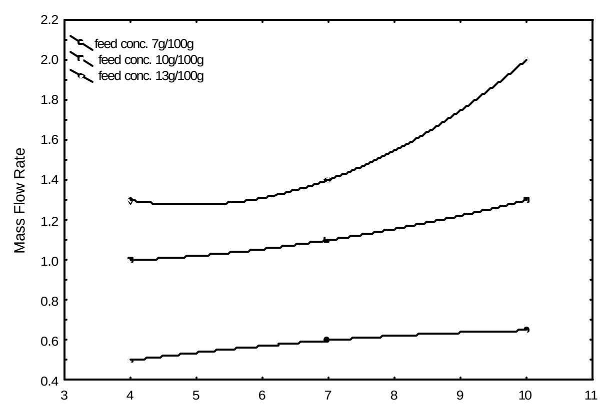

Fig (7): Effect of pool level versus feed concentration on mass flow rate, other experimental conditions steam pressure 3bar, drum speed 4rpm.

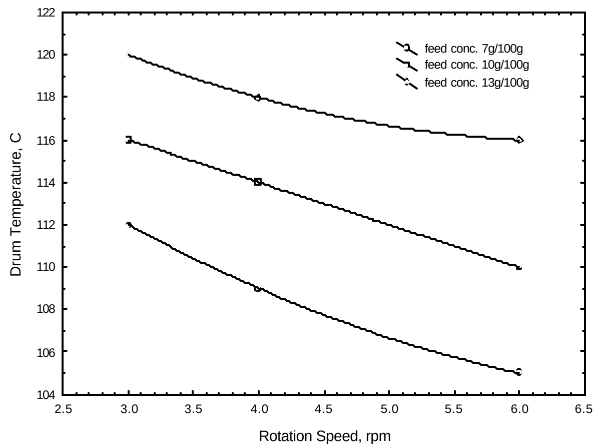

Fig (8): Effect of drum speed versus feed concentration on drum temperature, other experimental conditions steam pressure 3bar, pool level 7cm.

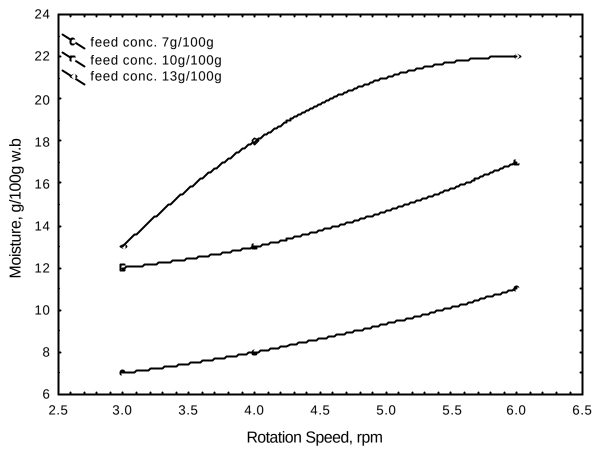

Fig (9): Effect of drum speed versus feed concentration on product moisture, other experimental conditions steam pressure 3bar, pool level 7cm.

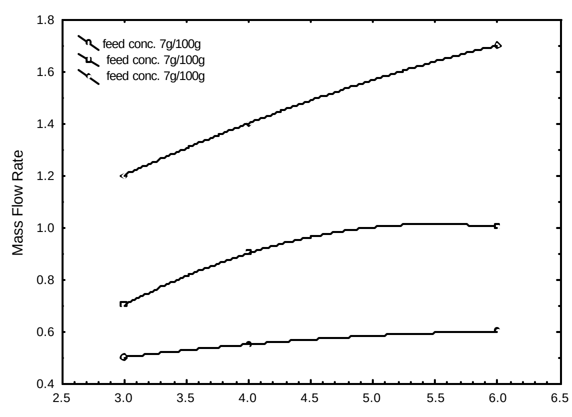

Fig (10): Effect of drum speed versus feed concentration on mass flow rate, other experimental conditions steam pressure 3bar, pool level 7cm.

Conclusions

Among the examined input variables (steam pressure, pool level, rotation speed and feed concentration) the concentration of the feed slurry appears to be more significant for the performance of the dryer. The effect of varying the steam pressure, pool level and rotation speed on the output variables is different at different feed concentrations. For a 7 g/100 g feed slurry the effect .is marginal while it becomes more pronounced as the concentration of the feed slurry increases. So for a 13 g/ 100 g slurry the product moisture, mass flow rate are the greatest regardless of the values of the other input variables. However, operating the dryer with a 13 g/100 g feed slurry often results in product sheets of uneven moisture. On the other hand, the less concentrated films dry easier but at much smaller product outflows. So from a practical point of view the 10 g/100 g slurry seems a reasonable compromise.

The variation of mass flow rate with respect to the other input variables. The behavior of the dryer with 7 g/100 g slurry is quite different and appears to be satisfactorily described by a gravity-driven free flow of the material in the pool between the very thin in this case boundary layers around the drums.

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