"Of Beer, Leather and Beets"
A Study of Alternative Binders in Agitation Pelletizing

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ABSTRACT

Agitation-type pelletizing requires the presence of a binder to form the agglomerates and to impart physical characteristics to the finished agglomerates to survive further processing.

When water alone does not yield sufficient results, other binders, in addition to the water, are used to enhance the physical characteristics of the agglomerate. This paper compares several alternative binders to other traditional binders.

The alternative binders are derivatives from the mashing and brewing of beer, the tanning of leather, the processing of waste leather and the processing of beets.

One of the most important aspects in the selection of agitation-type pelletizers is the testing phase. During this phase, several areas are researched including: material compatibility to the agitation pelletizing process, production of the specified finished pellet size and shape requirements, and the physical characteristics of the pellets.

Generally, the physical characteristics of the pellets determine if additional binders are required to enhance pellet drop, crush or attrition properties.

In the selection of binders, the criteria for selection are usually compatability of the binder with the material being pelletized, capabilities of the binder to perform the required enhancements to the pellets, and the best cost performance.

As previously mentioned, the testing phase of the agglomeration selection process is very important to determine if additional binders are needed, and if so, which binder best fits the selection criteria.

Oftentimes, when a binder is required, the end user of the pellets can give guidelines as to what is acceptable in the product (compatibility) and what the pellets are required to survive (capability) but is not knowledgeable of the various binders available and the consequent economical impact (cost). The decision to evaluate particular binders is usually up to the testing laboratory.

When we test materials that need additional binders, we recommend binders that meet the compatibility, capability and cost criteria, as well as binders that have performed well in similar circumstances. Since binders are an important part in successful agitation pelletizing, we are constantly looking for alternative binders that will meet the three "C's."

We contacted RDE, Incorporated, after hearing that it has several binders that could be viable alternatives to the binders that we usually recommend. We found that of the binders offered, some have been used in agglomeration processes but not generally in the agitation-type area. We then decided to pick three different materials and to test the binders on these materials, to determine if they meet the three "C's," and if they can be considered as viable alternative binders.

The test work described in this study deals strictly with the effect of the binders when the materials are pelletized on a rotating pan or deep drum pelletizer. It is not known what comparisons can be made when tested in other forms of agitation agglomerators, but it is generally accepted that improvements in physical characteristics that are observed on a Disc or Deep Drum pelletizer, will also be observed on other types of agitation pelletizers such as the Pin Mixer and other mixing agglomerators. There may be variations of the degree of improvements, but nonetheless, a similar trend of improvement.

BINDERS THAT WERE EVALUATED:

In this study, four binders were evaluated against other more common binders for overall pellet physical characteristics and cost. The binders evaluated were:

BREWEX:	A material derived from the mashing and brewing process
TAC:	A material derived from the tanning of animal hides
COLLAGEN CH_2:	A material from the alkaline hydrolysis of leather waste
MOLEX:	A material from sucrose extraction from beet molasses

COMPARISON BINDERS:
- WATER
- CANE MOLASSES
- AMMONIUM LIGNIN SULFONATE

TEST MATERIALS:
- IRON OXIDE
- LIMESTONE
- CARBON

BREWEX:

Brewex is a liquid modified starch material derived from the mashing and brewing process, which transforms malt, corn and/or rice into a fermentable substance from which beer is produced.

Much of the starch derived from grain is enzymatically converted to sugar in the mash tubs. Mash blends and hops are further processed in the brew kettle. In the brew kettle, this material, now called "wort," is adjusted for sugar content suitable for fermentation into beer.

The solids derived from screening grain residuals in the mash tubs and brew kettle are collected and centrifuged to separate brewers' grains from brewers' solubles. This is further processed to increase the solids content from about 12% to 50% in a multi-effect evaporator. This concentration process results in "Brewex," a sterilized material, which is further stabilized with propionic acid for storage.

Brewex has demonstrated the capability of replacing part or all of more costly starch binders to significantly reduce production costs in several applications, including charcoal briquettes, corrugation pastes and adhesive formulations. While starch may be required to provide wet strength in certain processes, the dry strength of Brewex has been found to be equal to, and even superior to, that of starch.

This, coupled with the other successes in the briquetting of metal ores and in the animal feed industry as a nutritive agglomerant, is why Brewex was chosen to be evaluated as an agitation-type pelletizer binder.

A typical analysis (DM) of Brewex is as follows:

PH	3.9 - 4.4
GLUCOSE	10.0%
MALTOSE	33.0%
MALTO-DEXTRINS	47.0%
PROTEIN	6.0%
ASH*	4.0%
	100.0%

*INCLUDES 435 PPM SULFUR

TAC:

TAC is a residual vegetable tannin resulting from the process of tanning animal hides to make sole leather.

In this process the hides are soaked in vats of vegetable tannin solutions. The residuals must be collected and resold since there is no landfill or other dumping allowed. These tannin liquors are concentrated and spray dried at the Westfield Tanning Company, Westfield, Pennsylvania.

The practical applications of this material are as retan agents and industrial binders. A similar material, not tested for comparison in this paper, is TRM, produced by Howes Leather Company. TRM is sold currently as a binder for limestone pellets.

A typical analysis (DM) is:

MOISTURE	5.0%
TANNINS	38.0%
PROTEIN	12.0%
CARBOHYDRATE	15.0%
ASH	30.0%
	100.0%

TAC is also available in liquid form with 35%-40% solids content. The test work was performed with the liquid TAC.

COLLAGEN CH_2:

Collagen CH_2 is now in pilot production only. This unique substance results from the alkaline hydrolysis of leather waste (chrome shavings and trimmings) . This project was begun by U.S. Leather Holdings, Milwaukee, Wisconsin, to solve landfill problems before they became more acute.

In this process, the leather waste is digested so that two fractions are produced. The trivalent chrome is recycled for tanning use and the collagen (hide protein) is reduced to polypeptides. This material has been approved for certain applications by industrial adhesive producers to replace casein and/or other similar materials.

A typical analysis (as is) is as follows:

MOISTURE	60.0%
PROTEIN	36.0%
ASH	4.0%
CHROME	10 PPM

MOLEX:

Molex is the result of new technology to extract sucrose from beet molasses. This technology is being performed by Savannah Foods at its Fremont, Ohio refinery. This reduced-sugar-content form of beet molasses is produced in sufficient quantities to be an option for major agglomeration applications. This low-viscosity material has the following typical analysis (as is):

MOISTURE	40.0%
SUGAR	15.0%
CARBOHYDRATE (other)	17.0%
PROTEIN	12.0%
ASH	16.0%

The above binders were tested against water only, cane molasses and ammonium lignin sulfonate. Descriptions of these binders are as follows:

WATER:

The water used in the testing was ordinary tap water at room temperature.

MOLASSES:

The molasses was a cane molasses that had the following composition:

SOLIDS	72.0%
PHOSPHORUS	0.05%
ASH	8.2 %
CALCIUM	0.9 %
SULFUR	0.74%
MAGNESIUM	0.35%
POTASSIUM	2.5 %
PROTEIN	5.7 %
COPPER	59.6 PPM
IRON	200.0 PPM
WEIGHT	11.7 LBS/GAL

AMMONIUM LIGNIN SULFONATE:

The ammonium lignin sulfonate used for the testing was as offered by Inland Container Corporation, New Johnsonville, Tennessee. The product used was "Ligno 10 Ammonium Lignin Sulfonate," which is a brown liquid with a "woody" odor that is a by-product of paper production.

In the semichemical pulping process, wood fibers are sulfonated in closed vessels by which the lignin derivatives become soluble and separate from the cellulose fibers.

A typical analysis (as is):

MOISTURE	50.0%
REDUCING SUGARS	13.0%
LIGNIN SULFONATE	24.0%
ASH	13.0%

TEST MATERIALS:

The testing was performed on three (3) materials; iron oxide, limestone and carbon. The analysis of the feed materials is as follows:

IRON OXIDE:

The iron oxide is a by-product from a finish-line acid-bath process, and is Fe_20_3.

Moisture Content:	(as tested) - - - - - - 0.1%
Bulk Density:	(aerated) - - - - - - - 30.9 PCF
	(deaerated) - - - - - -42.5 PCF

Sieve Analysis:

MESH SIZE	PERCENT RETAINED	PERCENT ACCUMULATIVE
+ 10	0.3	0.3
- 10 + 45	0.7	1.0
- 45 + 80	27.2	28.2
- 80 +120	27.4	55.6
-120 +200	22.2	77.8
-200 +325	12.5	90.3
PAN	9.7	100.0

LIMESTONE:

The limestone is a ground limestone provided by James River Limestone Company in Buchanan, Virginia. The sample tested was from its Austinville plant, which currently pelletizes the material for marketing as an agricultural limestone.

Moisture Content: (as tested) - - - - - - - 0.5%
Bulk Density: (aerated) - - - - - - - - 93.3 PCF
(deaeratad) - - - - - - 122.3 PCF

Sieve Analysis:

MESH SIZE	PERCENT RETAINED	PERCENT ACCUMULATIVE
+ 10	0.1	0.1
- 10 + 45	28.9	29.0
- 45 + 80	22.7	51.7
- 80 +120	22.9	74.6
-120 +200	18.4	93.0
-200 +325	5.3	98.3
PAN	1.7	100.0

CARBON:

The carbon was supplied by the Carbon Graphite Group, Inc., Niagara Falls, New York. It is a petroleum coke from a coke unloading source. Typical analysis is:

ASH	0.42%
CARBON	99.58%
SULFUR	0.73%
MOISTURE	0.20%
VOLATILE	0.64%

Moisture Content: (as tested) - - - - 0.2%
Bulk Density: (aerated) - - - - - 45.3 PCF
(deaerated) - - - 69.1 PCF
Sieve Analysis:

MESH SIZE	PERCENT RETAINED	PERCENT ACCUMULATIVE
+ 10	0.7	0.7
- 10 + 45	0.4	1.1
- 45 + 80	12.4	13.5
- 80 +120	26.5	40.0
-120 +200	28.7	68.7
-200 +325	20.4	89.1
PAN	10.9	100.0

TEST PROCEDURE:

The testing was performed on laboratory-sized agitation-type pelletizing equipment.

The materials were hand fed to the pelletizer. Liquid binders were applied by hand via spray bottles.

All procedures were held as tightly as possible so that each material and binder run was identical, insofar as pelletizer pan speed, pelletizer operating angle and feed and spray locations.

Liquid binders were diluted with water at ratios to achieve 25% solids content in the mix. This allows comparison of the binders at equivalent solids content.

TEST EQUIPMENT:

PELLETIZER:

Mars Mineral Model DP-14 "Agglo-Miser" laboratory-size pelletizer. The "Agglo-Miser" was equipped with a 14" diameter pan, adjustable pan depth (3", 6" and 9"), variable-speed pan drive, adjustable operating angle and adjustable pan scrapers.

MOISTURE BALANCE:

Ohaus Moisture Determination Balance, Model 6100.

DRYING OVEN:

Blue M Electric Company, electric oven Model CO8A-3-10.

CRUSH TEST:

The pellet crush tests were performed on a compression tester as manufactured by John Chatillion & Sons, Inc.

SIEVE ANALYSIS:

Sieve analysis of the materials was performed on an automatic sieve shaker Model RX-24 as manufactured by Forney Testing Equipment Company. The screens were U.S. Standard.

TEST RESULTS:

The tests of the pellets were performed on "green," "air-dried" and "oven-dried" pellets.

Green pellets are pellets as they are discharged from the pelletizer.

Air-dried pellets are pellets that have been allowed to air dry at ambient temperatures for a period of 24 hours. No forced air or heat is applied to the air-dried pellets.

Oven-dried pellets are pellets that have been dried in an electric oven at 250° F to less than 0.5% moisture content (by weight).

All pellets tested were 1/4" by 3/8" diameter.

All attrition tests were performed on a No. 10 mesh screen, shaken on the sieve shaker for a period of five minutes.

Drop tests are the average number of drops that a pellet will survive when repeatedly dropped from a height of 18" onto a steel plate.

Crush tests are the average force in pounds applied to a single pellet to cause fracturing.

All cost data was based upon the binder usage at the 25% solids content level. The pricing information was based upon the delivered price of the undiluted binder to Pittsburgh, Pennsylvania.

Binder costs, F.O.B., Pittsburgh, PA per liquid pound:

BREWEX	\$0.03
TAC	0.05
COLLAGEN CH_2	0.13
MOLEX	0.03
CANE MOLASSES	0.05
LIGNO 10	0.04

Results of Tests No. 1, 2 and 3 are as follows:

TEST NO. 1
MATERIAL - IRON OXIDE

Green Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	34.0%	68.5 PCF	7.0	2.4	0.0
MOLASSES	28.3%	72.5 PCF	11.0	1.3	0.0
LIGNO 10	34.0%	62.7 PCF	29.0	1.0	0.0
BREWEX	28.7%	69.4 PCF	18.0	3.1	0.0
TAC	26.0%	63.2 PCF	4.0	0.3	0.0
COLLAGEN	28.5%	63.3 PCF	11.0	2.7	0.0
MOLEX	30.6%	61.9 PCF	3.0	0.6	0.0

Air-Dried Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	23.2%	61.0 PCF	3.0	2.4	11.3%
MOLASSES	21.0%	66.9 PCF	6.0	1.1	0.5%
LIGNO 10	22.0%	60.0 PCF	5.0	1.0	1.1%
BREWEX	27.0%	62.8 PCF	7.0	2.1	20.8%
TAC	20.0%	55.9 PCF	4.0	0.5	17.2%
COLLAGEN	24.2%	60.1 PCF	5.0	2.8	1.2%
MOLEX	28.0%	58.1 PCF	3.0	0.7	0.6%

Oven-Dried Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	0.1%	45.7 PCF	1.0	0.8	100.0%
MOLASSES	0.1%	51.0 PCF	50+	16.3	0.6%
LIGNO 10	0.1%	44.7 PCF	50+	10.3	2.6%
BREWEX	0.1%	46.4 PCF	32.0	16.7	1.3%
TAC	0.1%	39.0 PCF	9.0	2.5	26.6%
COLLAGEN	0.1%	47.5 PCF	17.0	20.0	1.3%
MOLEX	0.1%	41.6 PCF	9.0	8.7	0.8%

SUMMARY:

Brewex and Collagen CH_2 performed equal to or better than molasses and Ligno 10.

Molex did not perform as well, but produced pellets with good physical characteristics.

TAC did not perform as well as the rest of the binders tested.

TEST NO. 2
MATERIAL - LIMESTONE

Green Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	8.0%	87.6 PCF	7.0	1.4	1.2%
MOLASSES	6.0%	83.6 PCF	8.0	3.2	0.4%
LIGNO 10	6.1%	82.4 PCF	6.0	2.7	0.0%
BREWEX	6.0%	82.8 PCF	5.0	1.9	0.4%
TAC	6.2%	77.7 PCF	5.0	1.3	0.6%
COLLAGEN	5.8%	88.8 PCF	8.0	1.9	0.0%
MOLEX	6.8%	83.0 PCF	5.0	2.7	1.8%

Air-Dried Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	3.5%	78.5 PCF	2.0	1.8	30.4%
MOLASSES	3.0%	78.6 PCF	4.0	3.6	6.9%
LIGNO 10	3.0%	77.8 PCF	19.0	5.2	2.9%
BREWEX	1.0%	75.9 PCF	50 +	3.4	1.9%
TAC	2.8%	72.4 PCF	4.0	4.2	6.8%
COLLAGEN	1.2%	76.6 PCF	50 +	7.7	0.5%
MOLEX	2.5%	79.8 PCF	7.0	4.3	15.5%

Oven-Dried Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	0.1%	75.4 PCF	1.0	1.3	100.0%
MOLASSES	0.1%	76.9 PCF	45.0	49.4	0.4%
LIGNO 10	0.1%	70.3 PCF	50 +	48.0	0.9%
BREWEX	0.1%	72.7 PCF	50 +	35.4	1.5%
TAC	0.1%	65.9 PCF	6.0	12.2	2.7%
COLLAGEN	0.1%	73.4 PCF	50+	80+	0.2%
MOLEX	0.1%	73.7 PCF	50+	45.7	1.5%

SUMMARY

Collagen CH_2 was the best performer in this test, with Brewex a close second. Both equalled or surpassed the molasses and Ligno 10 results.

Molex also performed well, except for increased attrition losses.

TAC did not perform as well as the rest of the binders tested.

TEST NO. 3
MATERIAL - CARBON

Green Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITTON
WATER	22.0%	54.6 PCF	2.0	0.1	1.5%
MOLASSES	17.0%	53.5 PCF	4.0	0.1	3.6%
LIGNO 10	19.0%	51.6 PCF	4.0	0.1	3.2%
BREWEX	19.0%	52.2 PCF	3.0	0.1	4.8%
TAC	18.0%	51.2 PCF	4.0	0.1	0.0%
COLLAGEN	17.0%	51.7 PCF	4.0	0.1	9.2%
MOLEX	18.0%	55.1 PCF	5.0	0.1	4.4%

Air-Dried Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	14.0%	47.3 PCF	1.0	0.1	80.3%
MOLASSES	10.0%	47.6 PCF	3.0	0.1	56.9%
LIGNO 10	14.0%	49.8 PCF	3.0	0.1	34.5%
BREWEX	9.0%	48.1 PCF	2.0	0.1	50.7%
TAC	12.0%	50.8 PCF	3.0	0.1	14.1%
COLLAGEN	10.0%	50.1 PCF	11.0	0.1	0.2%
MOLEX	15.5%	53.3 PCF	3.0	0.1	7.4%

Oven Dried Pellets

BINDER	MOISTURE	DENSITY	DROP	CRUSH	ATTRITION
WATER	0.1%	N/A	1.0	0.1	100.0%
MOLASSES	0.1%	42.6 PCF	27.0	17.1	3.9%
LIGNO 10	0.1%	40.5 PCF	50 +	18.0	6.2%
BREWEX	0.1%	39.4 PCF	26.0	10.0	4.6%
TAC	0.1%	43.3 PCF	50 +	8.3	13.5%
COLLAGEN	0.1%	43.7 PCF	50 +	18.9	7.2%
MOLEX	0.1%	46.3 PCF	50 +	19.7	3.8%

SUMMARY

In this series of tests, all binders tested equalled or surpassed the performance of molasses and Ligno 10, in the majority of catagories.

COST COMPARISONS

The following cost figures are based upon the amount of binder required to produce one (1) ton (2,000 pounds) of dried pellets. The cost figures are based upon the binders delivered to Pittsburgh, Pennsylvania, in tank truck quantities.

BINDER	IRON OXIDE	LIMESTONE	CARBON
MOLASSES	$18.80	$3.04	$9.75
LIGNO 10	27.44	3.46	12.59
BREWEX	16.13	2.56	9.38
TAC	29.40	5.51	18.29
COLLAGEN	85.47	13.34	44.38
MOLEX	14.70	2.43	7.32

SUMMARY

Our test work finds that there are viable binder alternatives when rating them on a cost/performance basis.

These binders have helped us by expanding the possible binder selections, enabling us to offer our customers an enhanced binder evaluation on their materials. It is likely that others will also benefit in applications for materials not included in this report.

These products – BREWEX, TAC, COLLAGEN CH_2 and MOLEX – gave varying degrees of success, as follows:

COLLAGEN CH_2 performed very well on all three materials tested in the oven-dried category, but could be cost prohibitive.
MOLEX performed well in the oven-dried category for limestone and carbon, but not iron oxide.
TAC produced good results in carbon pelletizing, but not for limestone and iron oxide.
BREWEX performed well on all three materials.

It should be noted that the dosages were selected for the purpose of comparing the binders on an equal solids content basis. It is possible that the dosages can be decreased without severely affecting the physical properties of the pellets. A reduction in dosage will decrease the cost of the binder in each application.

When all is taken into consideration, the alternative binders performed well and should be considered when searching for a binder in agitation pelletizing.