VINCENT KP-6L SOLIDS SEPARATOR PERFORMANCE TEST RESULTS USING THE UNIVERSITY OF TENNESSEE TESTING PROTOCOL

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INTRODUCTION

Confined animal production systems utilizing hydraulic-flush manure collection and transport systems use different methods of solids separation to achieve an effluent low enough in total solids to be recycled as flush water. Mechanical solids separators provide one method of solids reduction for flush systems. The performance of mechanical manure solids separators can vary dramatically with different total solids input concentrations. To properly size and install mechanical manure solids separation units, the separators' performance characteristics must be known for the manure slurry found at the farm in question. The results of these performance tests provide information a planner can use to estimate the expected through-put of material, the resulting mass of solids to be removed and the total solids (TS) content of the recovered solids expected from a given manure slurry. This is important information when sizing process sumps and solids storage areas; it is critical to selecting a unit that can be operated in the time frame desired by the producer. The nutrient partitioning data can be used by nutrient management planners to estimate the mass of nutrients remaining with the recovered solids.

In an effort to provide comparable performance data with a common basis for the selection of mechanical separators, the Biosystems Engineering and Environmental Science Department at The University of Tennessee has developed a standard testing protocol for mechanical manure solids separators. This protocol is designed to provide consultants, engineers and producers with separator performance data across a range of manure total solids input concentrations. The University of Tennessee Biosystems Engineering and Environmental Science Department has the capability to provide field-scale performance testing of manure solids separators with either dairy or swine manure slurries at two university experiment station locations.

The results of the separator performance testing are a comprehensive analysis of the unit, including; press-liquor flow rates over a range of influent total solids (TS) concentrations and the resulting press-cake moisture content, dry-mass capture efficiency, and nutrient partitioning of total kjeldahl nitrogen (TKN), total phosphorus (TP), and soluble phosphorus (SP).

UNIT DESCRIPTION

This report presents the results from testing a *Vincent* KP-6L screw-press (*Vincent Corporation*, Tampa, FL). The *Vincent* KP-6L screw-press was tested with a 0.05" round perforated screen. Two screws were tested; both were 6-inch in diameter with an interrupted flight. The first screw had a smooth flight (the plain screw). The second screw had a $^3/_8$ x $^3/_8$" notch every $^3/_8$" along the flight (the notched screw). Testing was preformed on December 12 – 14, 2000 at The University of Tennessee Dairy Experiment Station in Lewisburg, TN.

SEPARATOR TESTING

For the separator performance tests with dairy waste slurry, raw dairy manure and bedding were collected and stored for 48 hours prior to testing. Recovered dairy manure solids are used as bedding material at the UT Dairy Experiment Station where the testing was conducted. The manure and bedding mixture was approximately 20% TS. Each performance test began with a 500 gal (1890 L) tank containing waste with approximately 10% TS. To make 10% TS slurry, collected manure and bedding were mixed with dilution water for 30 minutes using an electric

paddle stirrer. The manure slurry was then pumped from the tank to the separator system using a centrifugal wastewater pump (Model #N267-F, *Zoeller Pump Co*., Louisville, KY). To achieve maximum flows, manure slurry was pumped to the separator at a rate exceeding the input capacity of the unit. Overflow piping carried excess manure slurry back to the waste sump.

Samples were collected from the influent and effluent points of the unit. Effluent solids are referred to as press-cake, and effluent liquids are referred to as press-liquor. Test duration was based on the time required to recover approximately 50 gal (190 L) of press-liquor. Resulting press-cake and press-liquor volumes were weighed using *Tru-test* load cells (Model #703, *Tru-test*, Mineral Wells, TX). After testing the separators at 10% TS, the mix in the tank was diluted to approximately 8% TS, the separator was again tested. Subsequently, tests were performed at approximately 6, 4, 2 and 1% TS. Samples were analyzed for total and volatile solids using Standard Method 2540. G (*Standard Methods*, 1998), SP using QuikChem method 12-115-01-1-H (*Lachat Instruments*, Milwaukee, WI), TP using QuikChem method 13-115-01-1-B (*Lachat Instruments*, Milwaukee, WI), TKN using QuikChem method 13-107-06-2-D (*Lachat Instruments*, Milwaukee, WI).

RESULTS

All data for the KP-6L tested at the UT Dairy Experiment Station in Lewisburg is provided in Appendices A & B of this report. Appendix A provides the data set from the test. Appendix B provides graphs of the data set.

Plain Screw

While the screw-press was equipped with the 6" diameter plain interrupted flight screw, the system was tested with input TS concentrations ranging from 0.5 to 8.3%. The press-liquor flow rate through the separator system increased as influent TS concentration decreased (Figure 1). The maximum press-liquor flow rate of 28.3 gpm occurred at an influent TS concentration of 0.5%. At 8.3% TS, the system achieved a flow rate of 4.8 gpm. The system maintained a consistent press-cake moisture content throughout the test (Figure 1). The average TS concentration of the press cake was 22.1% (± 2.4%).

The dry-mass capture efficiency of the separator system decreased with decreasing input TS concentrations. The maximum dry-mass capture efficiency occurring at an input TS of 8.3% was 53.6% (Figure 2). The minimum dry-mass capture efficiency occurring at an input TS of 0.5% was 3.5%. Dry-mass capture efficiency was calculated as follows:

$$\text{Dry-mass capture efficiency (\%)} = \frac{m_{in}\left(\%TS_{in}\right) - m_{PL}\left(\%TS_{PL}\right)}{m_{in}\left(\%TS_{in}\right)} \times 100 = \frac{m_{PC}\left(\%TS_{PC}\right)}{m_{in}\left(\%TS_{in}\right)} \times 100$$

Where m_{in} is influent mass, m_{PL} is mass press-liquor and m_{PC} is mass press-cake.

Nutrients were considered to be partitioned when the percentage of the nutrient recovered in the press-cake was greater than the percentage of manure mass recovered in the press-cake. When the influent TS concentration was between 0.5 and 6.0%, TP and TKN were partitioned into the press cake (Figure 3). At 8.3% TS, TP and TKN were not partitioned into the press-cake. Soluble phosphorus was never partitioned into the press-cake during tests with the plain screw. The percentage of SP recovered in the press-cake was always less than the percentage of manure mass recovered in the press cake. Percentage of influent constituent recovered in the press-cake was calculated as follows:

$$\text{Percentage in press cake} = \frac{m_{PC-constituent}}{m_{in-constituent}} \times 100$$

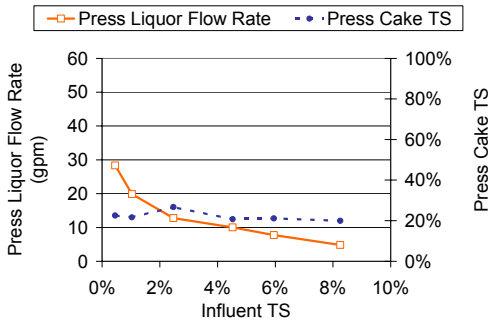

FIGURE 1. Press-Liquor Flow Rate (gpm) and Press-cake Total Solids (TS, %) from the KP-6L Equipped with the Plain Screw (0.050") as a Function of Influent TS (%).

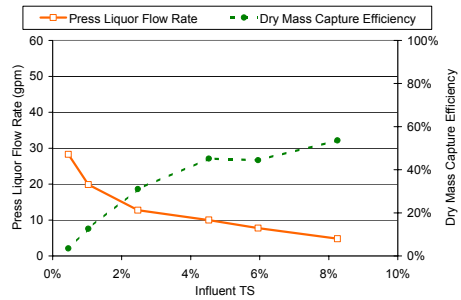

FIGURE 2. Dry-Mass Capture Efficiency by the KP-6L Equipped with the Plain Screw (0.050" screen) as a Function of Influent Total Solids (%).

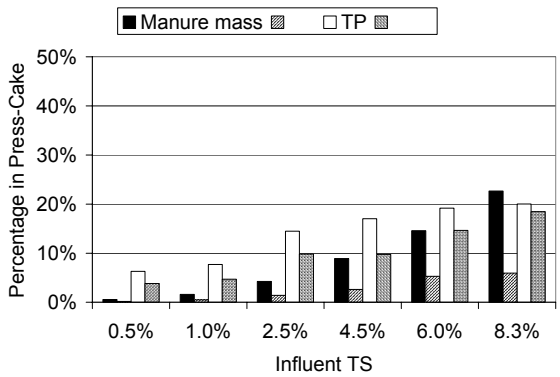

FIGURE 3. Nutrient Partitioning: Percentage of Influent Constituent Recovered in the Press-Cake, on a Wet Basis.

Notched Screw

While the screw-press was equipped with the 6" diameter notched interrupted flight screw, the system was tested with input TS concentrations ranging from 0.4 to 7%. The separator press-liquor flow rate increased as influent TS concentration decreased (Figure 4). The maximum press-liquor flow rate of 53.2 gpm occurred at an influent TS concentration of 0.4%. At an influent concentration of 7% TS, the separator achieved a press-liquor flow rate of 7.9 gpm. The screw-press maintained a press-cake with a TS concentration of 28.9% (± 1.2%) while the influent TS range was between 0.4 and 7% (Figure 4).

The dry-mass capture efficiency of the separator increased with an increasing influent TS concentration. The maximum dry-mass capture efficiency was 60% at an input TS of 7%. The minimum dry-mass capture efficiency of 4.3% occurred at an input TS of 0.4% (Figure 5).

At an influent TS concentration of 7%, 15% of the influent manure mass was recovered in the press-cake, on a wet-weight basis. The nutrient masses recovered in the press-cake (on a wet-weight basis) were 5% of the influent SP, 18% of the influent TP and 18% of the influent TKN (Figure 6). Because the percentage of TP and TKN recovered in the press-cake was greater than the percentage of manure mass recovered in the press-cake, these nutrients were being partitioned into the press-cake. Soluble phosphorus was not partitioned into the press-cake; the percentage of SP recovered in the press cake was less than that of manure recovered in the press-cake. Throughout the tests, TP and TKN were partitioned into the press-cake and SP was not.

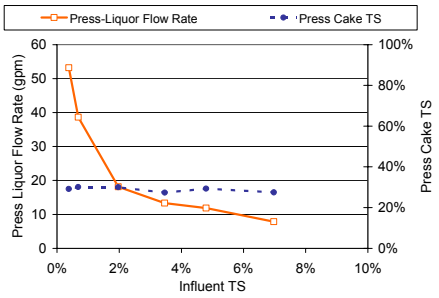

FIGURE 4. Press-liquor Flow Rate (gpm) and Press-cake Total Solids (TS, %) from the KP-6L Equipped with the Notched Screw (0.050") as a Function of Influent TS (%).

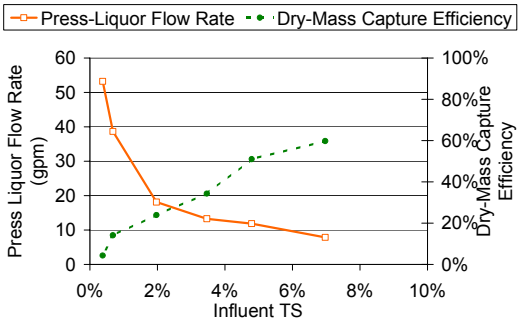

FIGURE 5. Dry-Mass Capture Efficiency by the KP-6L Equipped with the Notched Screw (0.050") as a Function of Influent Total Solids (%).

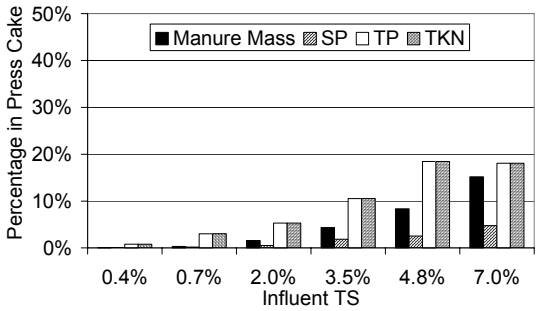

FIGURE 6. Nutrient Partitioning: Percentage of Influent Constituent Recovered in the Press-Cake, on a Wet Basis.

CONCLUSIONS

The University of Tennessee testing protocol developed for mechanical manure solids separators was used to quantify the performance of a *Vincent* KP-6L screw press having a 0.050" round perforated screen. The press was tested with a screw having a smooth interrupted flight and a screw having a notched interrupted flight. The notched screw had a $^3/_8$ x $^3/_8$" notch every $^3/_8$" along the flight. The press liquor flow rates from the notched screw were at least 25% greater than flow rates from the plain screw. The notched screw consistently produced a drier press cake; 29% total solids (TS) versus 21% TS from the plain screw. The mass of solids captured in the press cake (on a dry basis) was greater for the notched screw when the influent TS was greater than 4% and less than 1%. Between 1% and 4% influent TS, the plain screw had greater mass capture efficiency. The press partitioned total phosphorus and total kjeldahl nitrogen in the press-cake with both the plain and notched screw; neither screw partitioned soluble phosphorus in the press-cake.

VENDER CONTACT INFORMATION

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REFERENCES

Standard Methods for the Examination of Waste and Wastewater Treatment, 20th Edition. 1998. Clesceri L.S., A.E. Greenberg, A.D. Eaton eds. United Book Press Inc., Baltimore, Maryland.

Disclaimer Statement
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APPENDIX A

Sample Identification	Screw Type	% TS	% VS	Wet Wt.of eff.	mass in PC wet basis	Dry Wt. of Eff.	dry mass capture eff.	Vol of eff.	Time of run	Flow rate
		%	%	(lb)	%	(lb)	(%)	(gal)	(min)	(gpm)
Screw Press in	Plain	8.25%	82.22%	517.31		0.43			10	
Screw Press in	Plain	5.95%	81.17%	469.45		0.28			6.2	
Screw Press in	Plain	4.52%	82.90%	445.71		0.20			4.86	
Screw Press in	Plain	2.47%	81.90%	413.57		0.10			3.72	
Screw Press in	Plain	1.03%	83.71%	407.57		0.04			2.42	
Screw Press in	Plain	0.45%	86.85%	427.44		0.02			1.8	
Screw Press Cake	Plain	19.93%	90.02%	117.31	23%	0.23	53.61%		10	
Screw Press Cake	Plain	21.14%	91.97%	68.45	15%	0.14	44.47%		6.2	
Screw Press Cake	Plain	20.69%	90.79%	39.71	9%	0.08	45.20%		4.86	
Screw Press Cake	Plain	26.69%	91.13%	17.57	4%	0.05	31.03%		3.72	
Screw Press Cake	Plain	21.63%	95.24%	6.57	2%	0.01	12.66%		2.42	
Screw Press Cake	Plain	22.55%	92.95%	2.44	1%	0.01	3.50%		1.8	
Screw Press Liquor	Plain	4.95%		400		0.20		47.96	10	4.80
Screw Press Liquor	Plain	3.87%	74.52%	401		0.16		48.08	6.2	7.76
Screw Press Liquor	Plain	2.72%	74.18%	406		0.11		48.68	4.86	10.02
Screw Press Liquor	Plain	1.78%	74.64%	396		0.07		47.48	3.72	12.76
Screw Press Liquor	Plain	0.92%	75.27%	401		0.04		48.08	2.42	19.87
Screw Press Liquor	Plain	0.44%	84.81%	425		0.02		50.96	1.8	28.31

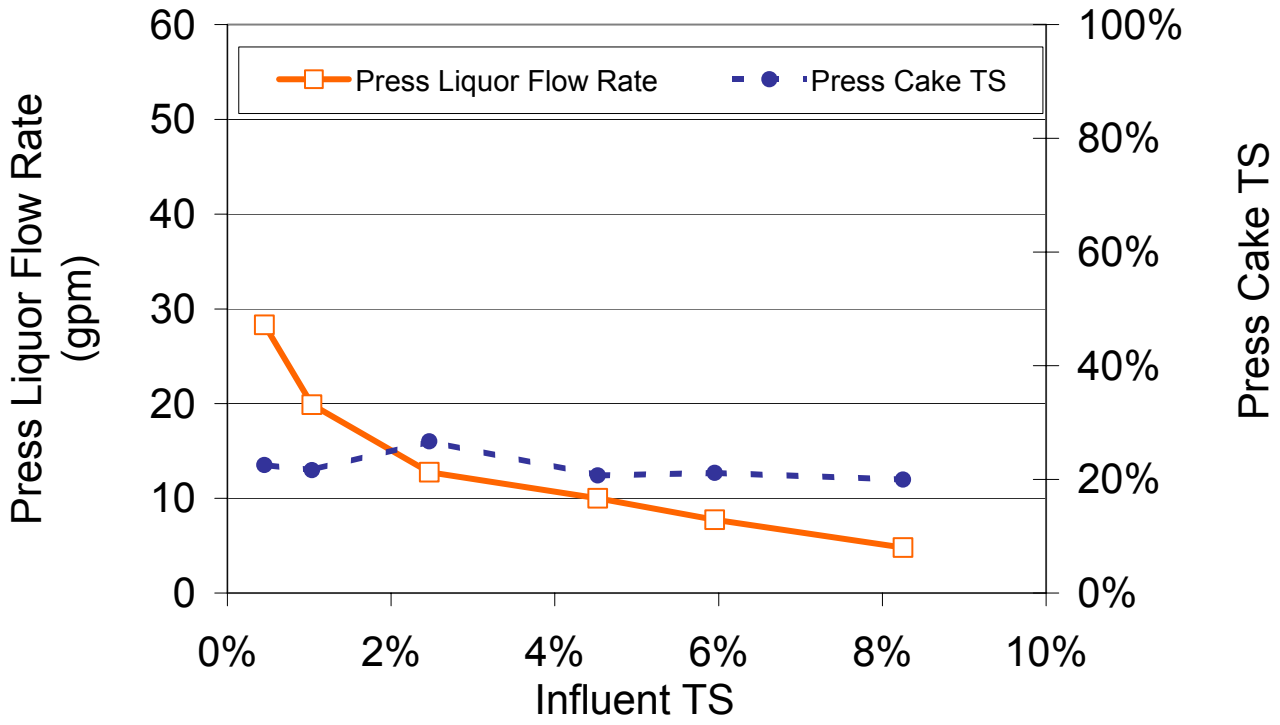
Sample Identification	Screw Type	S P conc. (mg/L)	S P mass g	% removed in PC	TP conc. mg/L	TP mass g	% removed in PC	TKN conc. mg/L	TKN mass g	% removed in PC
Screw Press in	Plain	86.7	20.36	6%	849	199.40	20%	4522	1062.03	18%
Screw Press in	Plain	75.6	16.11	5%	686	146.21	19%	3659	779.84	15%
Screw Press in	Plain	67.2	13.60	3%	457	92.48	17%	2501	506.08	10%
Screw Press in	Plain	50.4	9.46	1%	236	44.31	14%	1498	281.27	10%
Screw Press in	Plain	41.4	7.66	1%	137	25.35	8%	711	131.56	5%
Screw Press in	Plain	33.6	6.52	0%	70	13.58	6%	312.6	60.66	4%
Screw Press Cake	Plain	22.8	1.21		750	39.94		3685	196.26	
Screw Press Cake	Plain	27.36	0.85		902	28.03		3673	114.14	
Screw Press Cake	Plain	19.74	0.36		874	15.76		2737	49.34	
Screw Press Cake	Plain	16.86	0.13		804	6.41		3471	27.69	
Screw Press Cake	Plain	13.22	0.04		654	1.95		2076	6.19	
Screw Press Cake	Plain	9.58	0.01		773	0.86		2096	2.32	
Screw Press Liquor	Plain	101.4	18.41		852	154.72		4230	768.17	
Screw Press Liquor	Plain	64.2	11.69		629	114.51		3040	553.44	
Screw Press Liquor	Plain	64.5	11.89		420	77.42		2175	400.90	
Screw Press Liquor	Plain	45.9	8.25		275	49.44		1492	268.24	
Screw Press Liquor	Plain	37.2	6.77		129	23.48		581	105.77	
Screw Press Liquor	Plain	29.7	5.73		63	12.16		269	51.90	

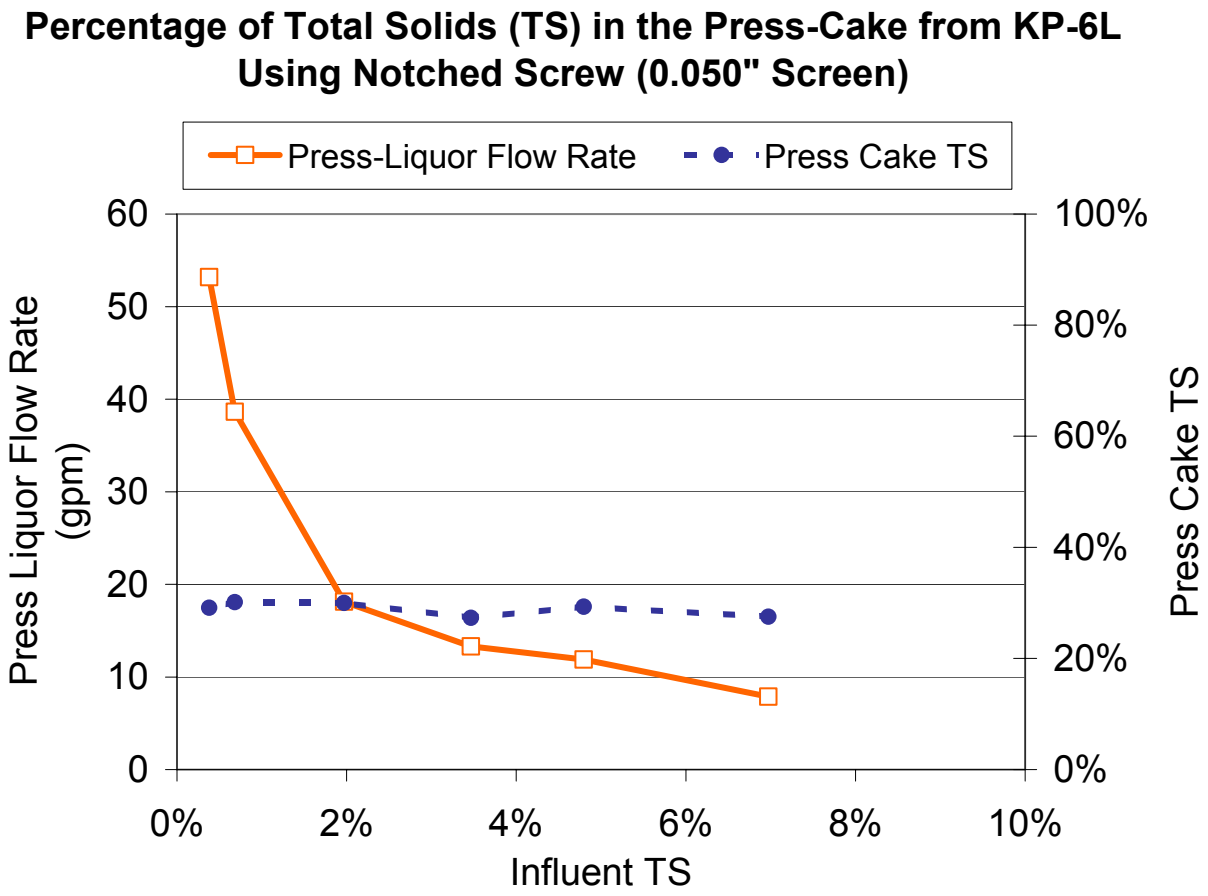
Sample Identification	Screw Type	% TS	% VS	Wt. of eff.	mass in PC wet basis	Dry Wt. of Eff.	dry mass capture eff	Vol of eff.	Time of run	Flow rate
		%	%	(lb)	%	(lb)	%	(gal)	(min)	(gpm)
Screw Press in	Notched	6.97%	82.62%	426.75		0.30			5.52	
Screw Press in	Notched	4.79%	79.71%	450.6		0.22			4.17	
Screw Press in	Notched	3.47%	82.79%	426.58		0.15			3.68	
Screw Press in	Notched	1.97%	80.02%	417.56		0.08			2.72	
Screw Press in	Notched	0.68%	80.75%	420.34		0.03			1.3	
Screw Press in	Notched	0.38%	87.04%	419.237		0.02			0.78	
Screw Press Cake	Notched	27.48%	82.86%	64.75	15%	0.18	59.79%		5.52	
Screw Press Cake	Notched	29.30%	93.09%	37.6	8%	0.11	51.00%		4.17	
Screw Press Cake	Notched	27.32%	90.80%	18.58	4%	0.05	34.33%		3.68	
Screw Press Cake	Notched	30.00%	92.45%	6.56	2%	0.02	23.92%		2.72	
Screw Press Cake	Notched	30.11%	92.42%	1.34	0%	0.00	14.10%		1.3	
Screw Press Cake	Notched	29.15%	92.23%	0.237	0%	0.00	4.34%		0.78	
Screw Press Liquor	Notched	4.18%	75.83%	362		0.15		43.41	5.52	7.86
Screw Press Liquor	Notched	2.92%	74.48%	413		0.12		49.52	4.17	11.88
Screw Press Liquor	Notched	2.26%	75.82%	408		0.09		48.92	3.68	13.29
Screw Press Liquor	Notched	1.44%	84.40%	411		0.06		49.28	2.72	18.12
Screw Press Liquor	Notched	0.71%	78.82%	419		0.03		50.24	1.3	38.65
Screw Press Liquor	Notched	0.43%	83.50%	346		0.01		41.49	0.78	53.19

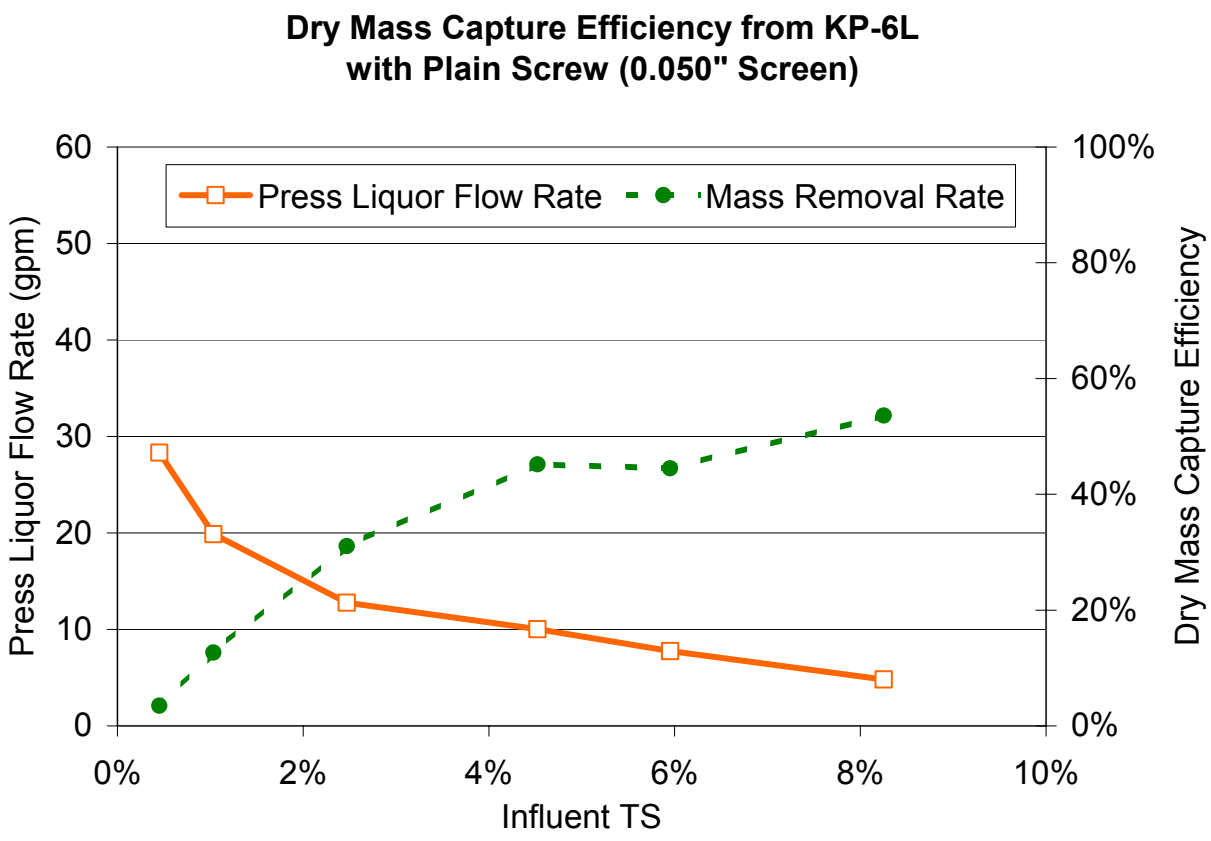
Sample Identification	Screw Type	SP conc. (mg/L)	SP mass g	% removed in PC	TP conc. mg/L	TP mass g	% removed in PC	TKN conc. mg/L	TKN mass g	% removed in PC
Screw Press in	Notched	64.2	12.44	5%	694.1	134.48	18%	3527	683.34	18%
Screw Press in	Notched	52.8	10.80	3%	469	95.94	18%	2647	541.50	14%
Screw Press in	Notched	39.9	7.73	2%	319	61.78	11%	1873	362.74	8%
Screw Press in	Notched	41.4	7.85	1%	244	46.26	5%	1210	229.38	4%
Screw Press in	Notched	29.1	5.55	0%	109	20.80	3%	450	85.88	3%
Screw Press in	Notched	25.5	4.85	0%	62.5	11.90	1%	205	39.02	1%
Screw Press Cake	Notched	20.16	0.59		828	24.34		4103	120.61	
Screw Press Cake	Notched	16.14	0.28		1038	17.72		4296	73.33	
Screw Press Cake	Notched	16.86	0.14		770	6.50		3227	27.22	
Screw Press Cake	Notched	13.62	0.04		820	2.44		3446	10.26	
Screw Press Cake	Notched	18.66	0.01		1036	0.63		3691	2.25	
Screw Press Cake	Notched	12.72	0.00		728	0.08		2500	0.27	
Screw Press Liquor	Notched	73.5	12.08		730	119.97		89.21	3907	
Screw Press Liquor	Notched	54.6	10.24		463	86.81		90.48	2402	
Screw Press Liquor	Notched	45.9	8.50		326	60.39		97.74	1770	
Screw Press Liquor	Notched	38.7	7.22		219	40.86		88.34	1182	
Screw Press Liquor	Notched	31.5	5.99		115	21.88		105.17	520	

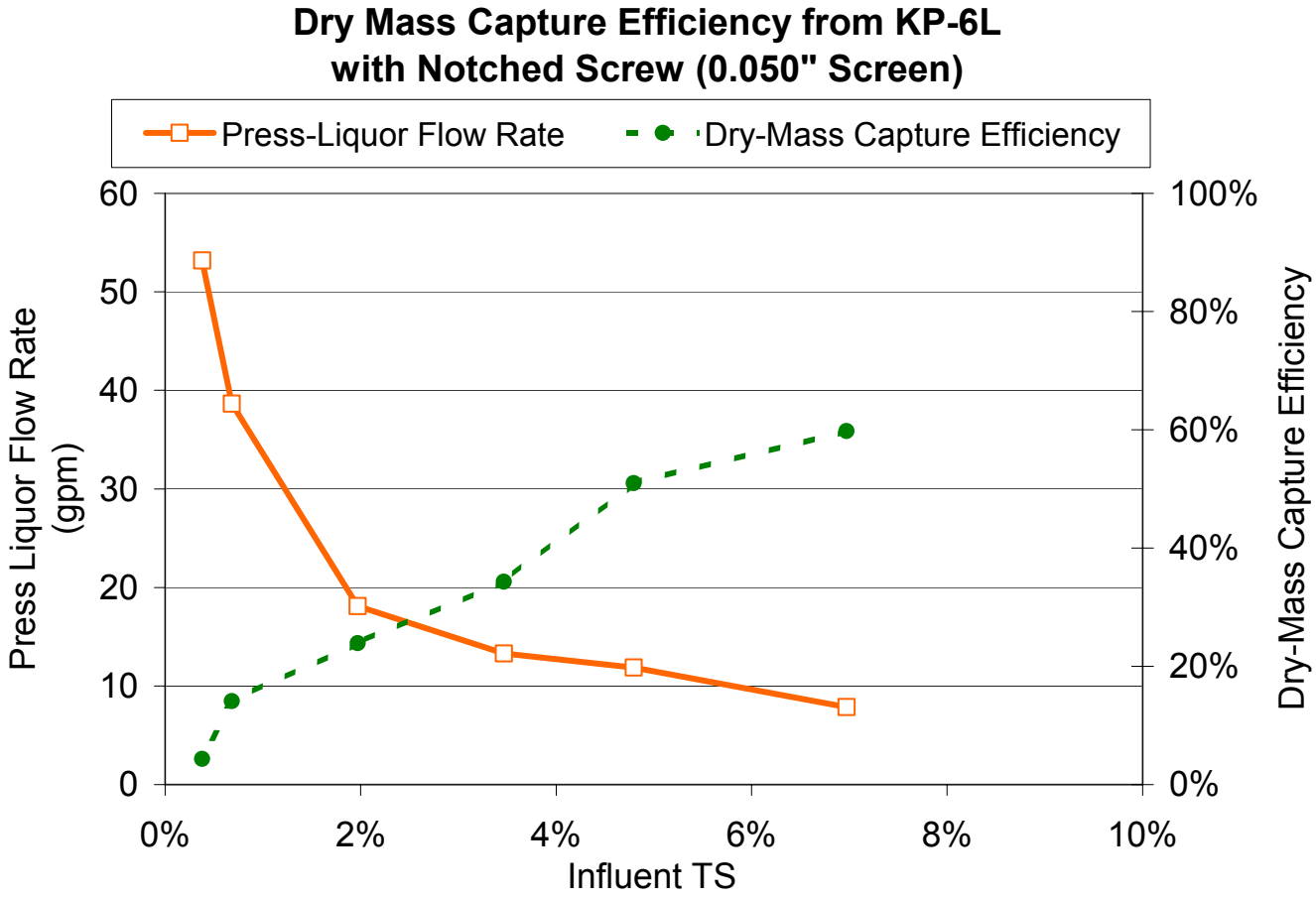
APPENDIX B

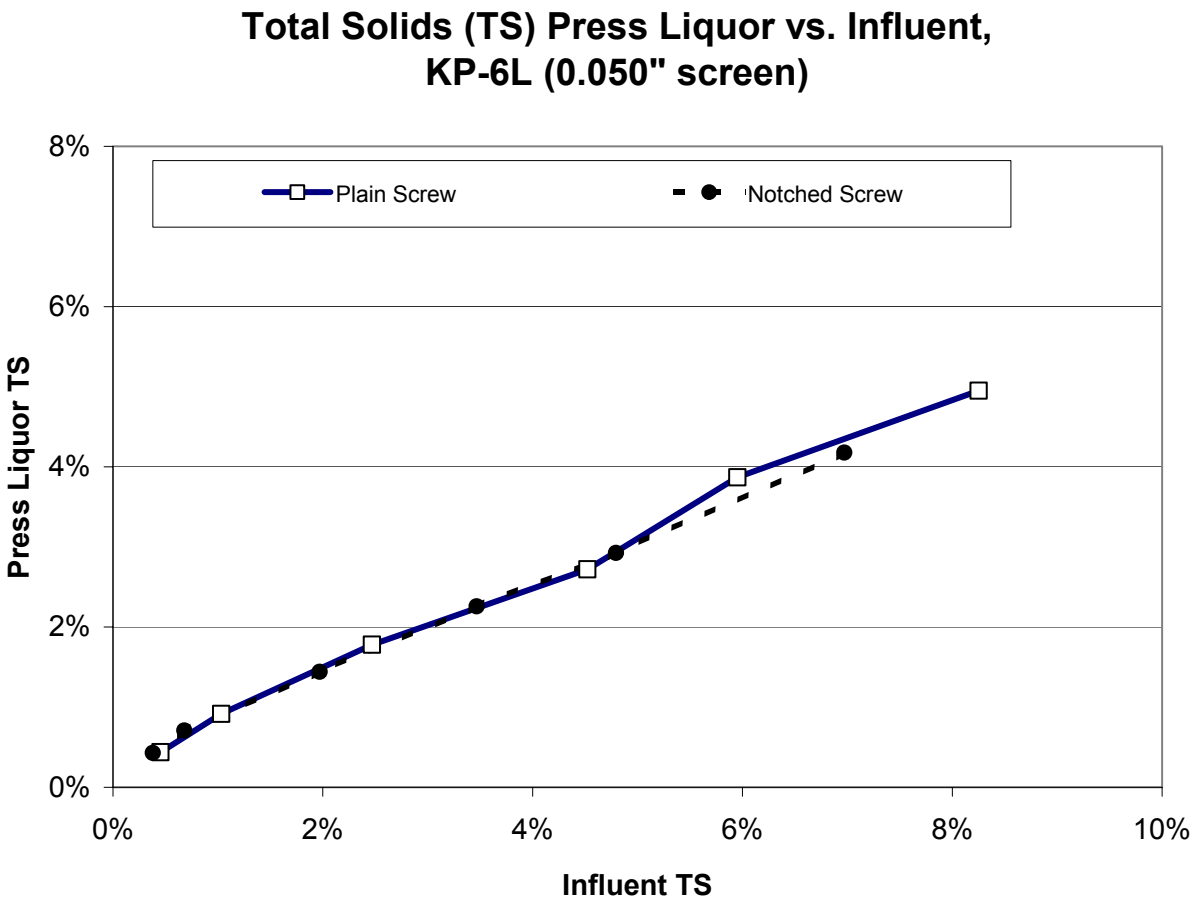
Percentage of Total Solids (TS) in the Press-Cake from KP-6L Using Plain Screw (0.050" Screw)

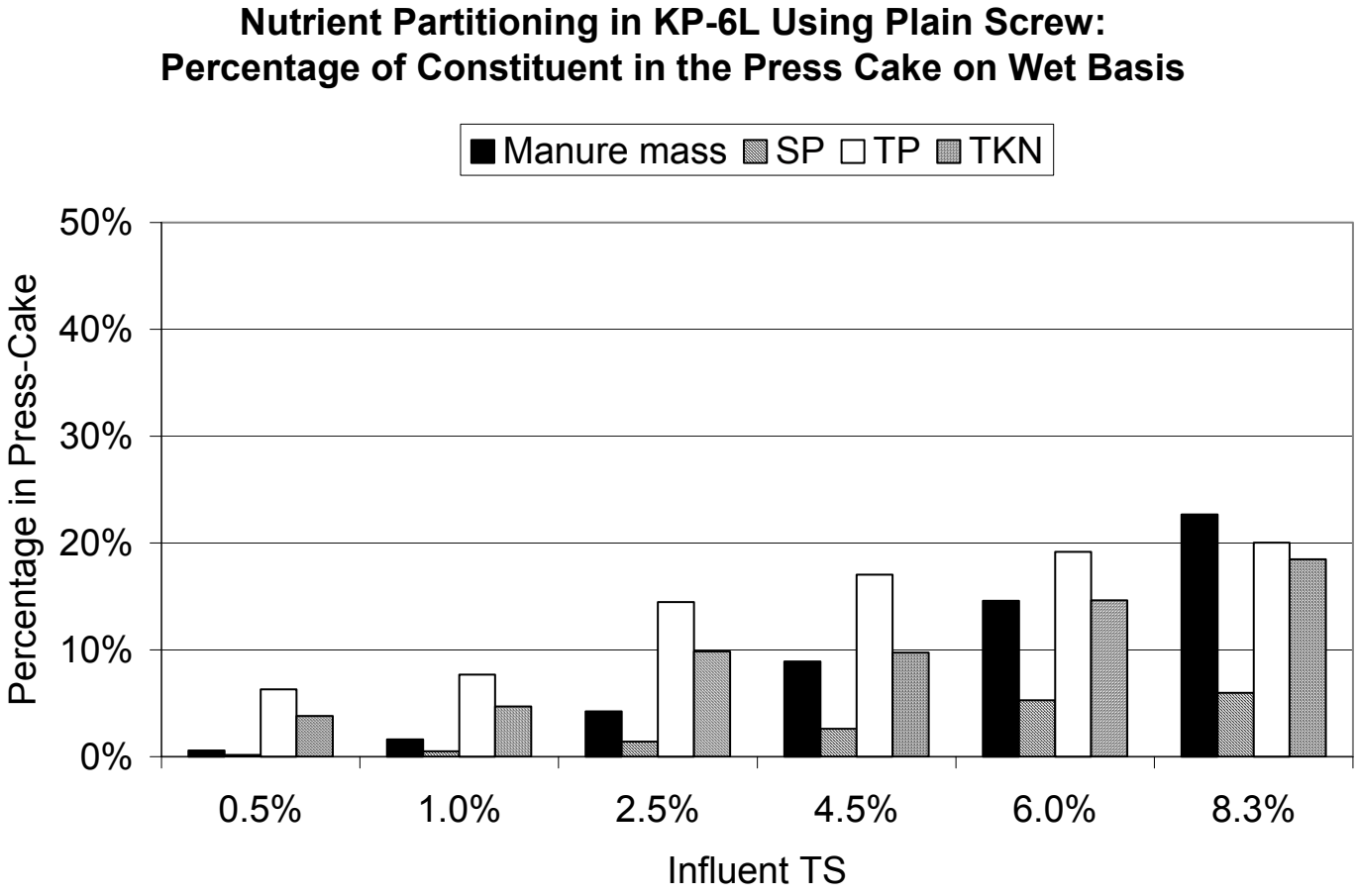



Percentage of Total Solids (TS) in the Press-Cake from KP-6L
Using Notched Screw (0.050" Screen)
Press-Liquor Flow Rate
Press Cake TS
Press Liquor Flow Rate (gpm)
Press Cake TS
Influent TS
0
10
20
30
40
50
60
0%
20%
40%
60%
80%
100%
0%
2%
4%
6%
8%
10%


Dry Mass Capture Efficiency from KP-6L
with Plain Screw (0.050" Screen)
Press Liquor Flow Rate
Mass Removal Rate
Press Liquor Flow Rate (gpm)
Dry Mass Capture Efficiency
Influent TS
0
10
20
30
40
50
60
0%
20%
40%
60%
80%
100%
0%
2%
4%
6%
8%
10%


Dry Mass Capture Efficiency from KP-6L
with Notched Screw (0.050" Screen)
Press-Liquor Flow Rate
Dry-Mass Capture Efficiency
Press Liquor Flow Rate (gpm)
Dry-Mass Capture Efficiency
Influent TS
0
10
20
30
40
50
60
0%
20%
40%
60%
80%
100%
0%
2%
4%
6%
8%
10%


Total Solids (TS) Press Liquor vs. Influent,
KP-6L (0.050" screen)
Plain Screw
Notched Screw
Press Liquor TS
Influent TS
8%
6%
4%
2%
0%
0%
2%
4%
6%
8%
10%


Nutrient Partitioning in KP-6L Using Plain Screw:
Percentage of Constituent in the Press Cake on Wet Basis
Manure mass
SP
TP
TKN
50%
40%
30%
20%
10%
0%
Percentage in Press-Cake
0.5%
1.0%
2.5%
4.5%
6.0%
8.3%
Influent TS

Nutrient Partitioning in KP-6L Using Notched Screw:
Percentage of Constituent in the Press Cake on Wet Basis