WASTEWATER CARBON SOURCES

A comparative study of common options and Aquafix's SmartBOD

Abstract

Comparison of three carbon sources and their effectiveness at wastewater treatment in batch reactors. Food supplements tested include; Molasses, Ol' Roy dog food, and a commercially available supplement supplied by AquaFix Inc.

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Reactor Design

Three batch reactors were constructed using 6” PVC pipe with a total volume of approximately 7L and a working volume of 5L. The reactors each had independent pH and dissolved oxygen controls in addition to monitoring temperature. A custom microcontroller interface was designed to control reactor set points, and to view real time sensor output.

Wastewater was obtained from the Stevens Point, Wisconsin municipal wastewater treatment facilitiy. The wastewater was diluted to 1500 mg/L MLSS concentration prior to the study start using city tap water.

Figure 1 shows a design schematic for a batch reactor used in the study.

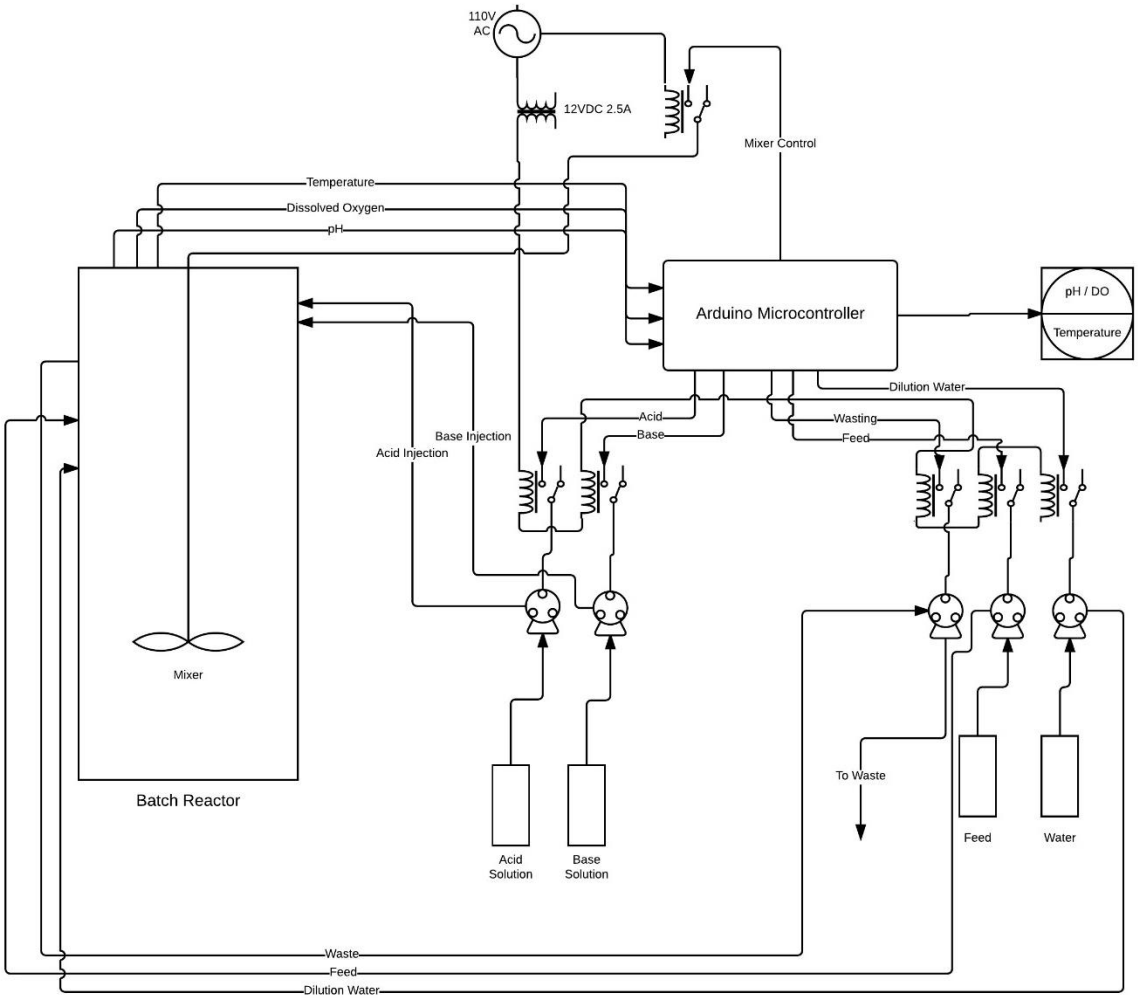

FIGURE 1: DESIGN SCHEMATIC FOR BATCH REACTORS

Experimental Conditions

Three carbon sources were used; molasses, Ol' Roy dog food[1], and SmartBOD. The reactors had the following controls; pH, dissolved oxygen, and mixing. Temperature was monitored, but not controlled. Mixing was achieved from an overhead mixer, in addition to aeration (when active). Conditions for the reactors are listed in Table 1.

TABLE 1: EXPERIMENTAL CONDITIONS.

Parameter / Condition	Setpoint
BOD of influent	To achieve 250 mg BOD / L * day^{-1}
pH	7.30-7.50
DO	2.8 mg/L DO
Temperature	Not controlled
Feed / Waste cycles per day	3
Volume decanted per day	1L
MLSS wasted per day	Varied per reactor, held MLSS at 1500 mg/L

A 5% solution of sodium carbonate, and 0.1M hydrochloric acid were used to control pH. An aquarium pump was used to control dissolved oxygen. Fresh solutions were made as necessary.

The amount of each food supplement differed based on supplied BOD values. Table 2 illustrates volumes added to each reactor per day to achieve a BOD concentration of 250 mg BOD / day.

TABLE 2: VOLUMES OF FOOD ADDED TO REACTORS.

Food Source	BOD	Food Added	Food Slurry	Dilution Water
	mg/g	*g/day*	*mL/day*	*mL/day*
Molasses	486	2.57	100	900
Ol' Roy	43	29.1	1000	0
Food Supplement	427	2.93	100	900

Concentrated mixtures of the molasses and SmartBOD were made, so that the required dosage rate in grams was added in 100mL. The Ol' Roy dog food had to be made up in a larger volume due to the higher viscosity of the slurry. The mixtures of the SmartBOD and dog food were continually mixed with an overhead mixer. All mixtures were stored at 4°C. Food mixtures were made fresh at least every other day.

Each reactor completed three cycles daily. Cycles consisted of treatment, settling, decant, feed/dilution phases. Each cycle lasted eight hours. Reactors settled for 30 minutes before decanting occurred. The feed and dilution phases occurred simultaneously.

[1]Ol' Roy dog food is a trademark of Wal-Mart Stores.

Test Methods

Reactors were tested for the following; ammonia, reactive phosphorus, chemical oxygen demand, flora count, mixed liquor suspend solids, and sludge volume index. Table 3 lists the method used for each test.

TABLE 3: LIST OF METHODS.

Test	Method
Ammonium (NH_3-N)	SM4500 NH_3H
Reactive Phosphorus (PO_4^{3-})	SM4500 PG
Chemical Oxygen Demand (COD)	SM 5220 D
Flora count	Toni Glymph
Mixed Liquor Suspended Solids (MLSS)	SM2540 D
Sludge Volume Index (SVI)	SM2710 D
Spectroscopy	In House

Ammonium and Reactive Phosphorus

Samples were collected from reactor effluent, filtered through a 0.45 µm membrane filter and preserved to a pH of < 2.0 with 1:1 H_2SO_4. Samples were analyzed by the Water and Environmental Analysis Laboratory located on the University of Wisconsin – Stevens Point campus.

Chemical Oxygen Demand

Reactor effluent samples were collected, filtered, and preserved with H_2SO_4 and refrigerated at 4°C until which time they could be analyzed. Chemical oxygen demand samples were analyzed in house.

Flora Count

A flora count, using a method developed by Toni Glymph was completed. Three slides were analyzed for each reactors MLSS. The different species of flora observed were tallied and averaged over the three slides. Results are reported as percent of total flora.

Mixed Liquor Suspended Solids

Samples of Mixed Liquor were removed from the reactor. The volume removed from the reactor was replaced with tap water to keep the 5L volume of the reactors consistent. Reactors were wasted as needed to keep MLSS at 1500 mg/L.

Sludge Volume Index

1L of the mixed liquor was removed from the reactor and allowed to settle for 30 minutes. The samples were then returned to the reactors.

Spectroscopy

An attempt was made to compare the MLSS values obtained from SM2540 D to uv-vis spectroscopy. Data was collected during the study, however it proved to be inconclusive. It was realized that during the study a background correction needed to be obtained to correct for color that developed in the reactors. Work on the comparison of absorbance values to MLSS concentrations will continue in future studies while correcting for background color.

Results & Discussion

Ammonium and Reactive Phosphorus

Effluent ammonium and reactive phosphorus were analyzed. Table 4 shows concentrations of each samples analyzed. It is unclear why the initial samples had high levels of ammonium and phosphorus in reactor effluent compared to later sample dates. It is possible that there was still carry over from the MLSS seed obtained from the Stevens Point wastewater treatment plant.

Ammonium did appear to accumulate in the reactor containing the Ol' Roy dog food, with low levels observed in the rest of the samples. Phosphorus accumulated in the reactor containing the dog food and molasses. Besides the initial sample low concentrations of ammonium and phosphorus were observed with SmartBOD.

TABLE 4: AMMONIUM AND REACTIVE PHOSPHORUS CONCENTRATIONS IN REACTOR EFFLUENT.

	NH_3-N (mg/L)			PO_4^{3-} (mg/L)		
Date	Molasses	Ol' Roy	SmartBOD	Molasses	Ol' Roy	SmartBOD
11/10/2016	0.07	0.39	<0.01	1.82	1.86	0.383
11/15/2016	0.02	0.02	<0.01	0.144	0.112	0.032
11/21/2016	0.05	0.43	0.04	0.195	0.155	0.039
11/28/2016	0.04	0.99	0.01	0.143	0.168	0.031

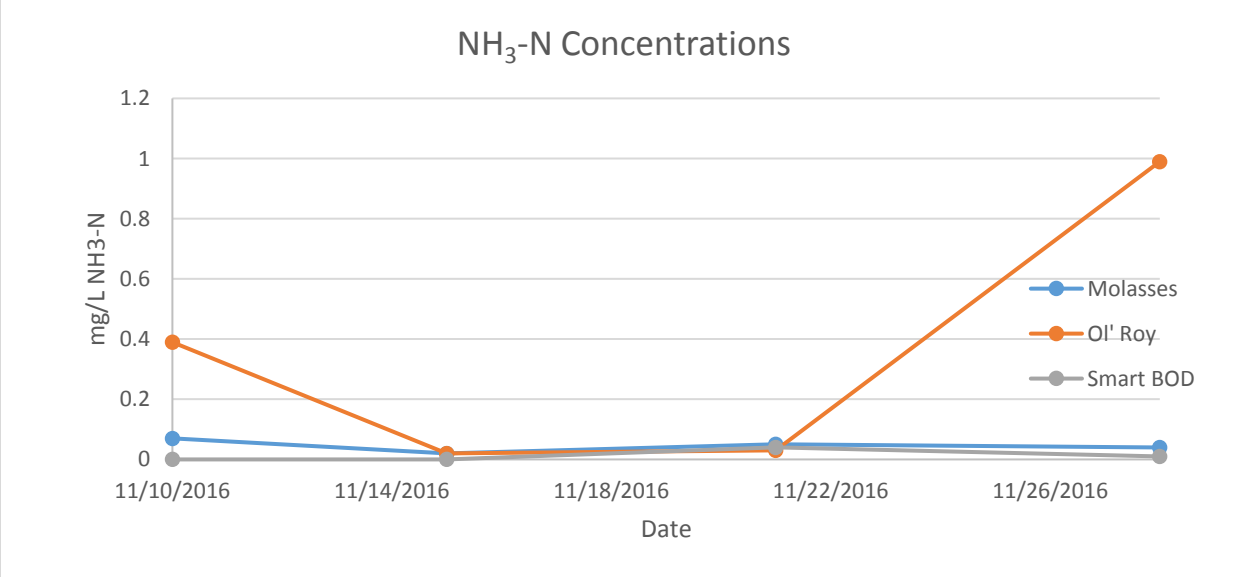

FIGURE 2: NH_3-N CONCENTRATIONS IN REACTOR EFFLUENT.

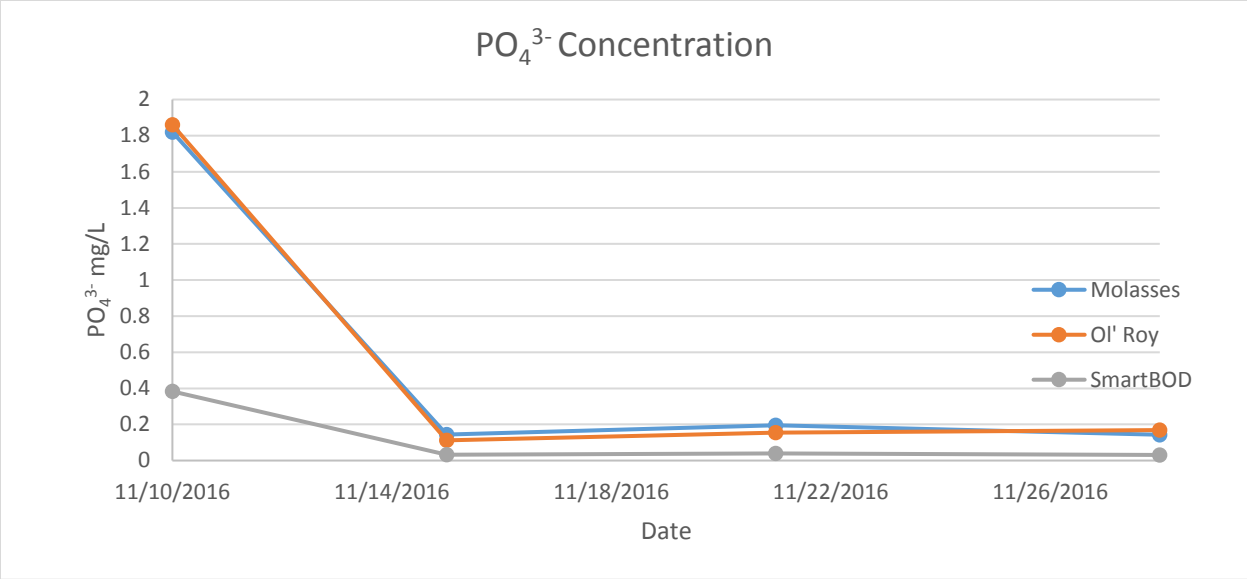

FIGURE 3: PO_4^{3-} CONCENTRATION IN REACTOR EFFLUENT.

Chemical Oxygen Demand

Effluent chemical oxygen demand was tested as a metric for the efficiency of treatment of the wastewater in the reactors. The reactor with the Ol' Roy dog food showed a clear increase in COD throughout the study, to nearly 1000 mg/L. This would indicate that treatment was not complete during reactor cycles and continued to accumulate. Both the molasses and the SmartBOD had low levels of COD in their effluent. All of the SmartBOD values, except for November 3rd and 9th were below 100mg/L COD, the rest were near or below 50 mg/L COD. This would indicate continuous, effective removal of the COD from the wastewater. Table 5 and Figure 4 contain COD results.

TABLE 5: COD CONCENTRATIONS IN REACTOR EFFLUENT.

	COD (mg/L)		
Date	**Molasses**	**Ol' Roy**	**SmartBOD**
11/3/2016	156.7	204.7	118.0
11/9/2016	155.4	468.1	115.8
11/12/2016	131.0	764.8	52.0
11/15/2016	125.2	832.9	39.0
11/22/2016	140.4	933.8	50.6
11/28/2016	200.9	909.4	46.2

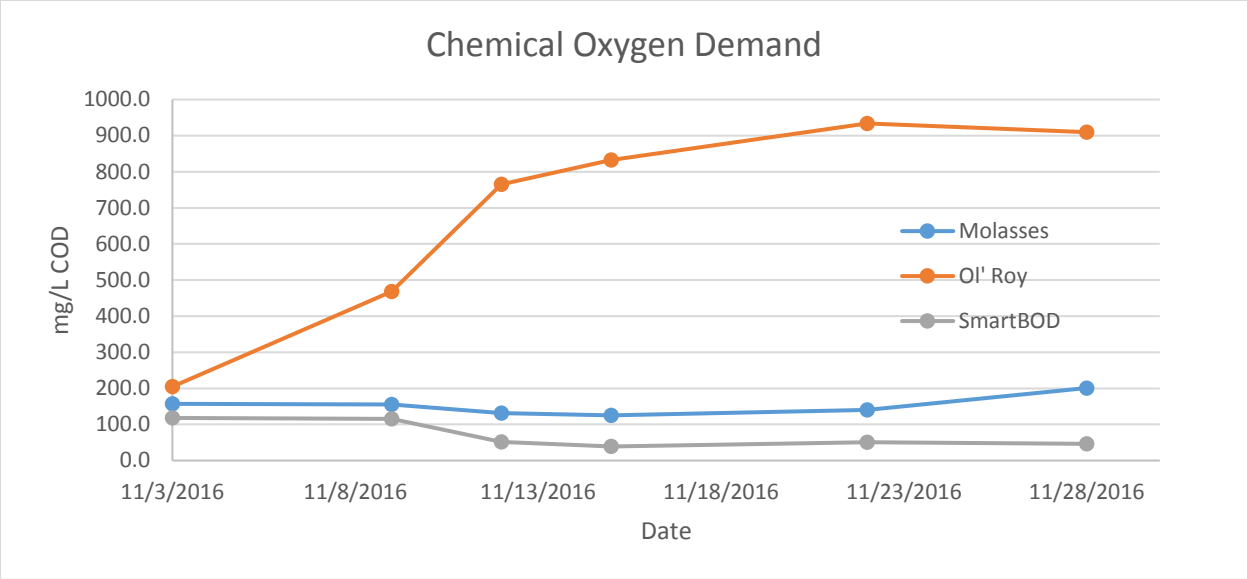

FIGURE 4: CHEMICAL OXYGEN DEMAND IN REACTOR EFFLUENT.

Flora Count

Microscope analysis of the MLSS was completed to look at the flora present in each reactor. The types of flora present can indicate the relative age, and health of a sludge. Healthier, younger sludges tend to have more flagellates and ciliates. Where older, less healthy sledges tend to have more amoebas, and metazoa.

TABLE 6: FLORA COUNT OF MLSS. RESULTS LISTED AS PERCENT OF TOTAL COUNT. MOLASSES (RX1), OL' ROY (RX2), AND SMARTBOD (RX3).

	Amoeba			Flagellate			Free Swimming Ciliates		
Date	Rx1	Rx2	Rx3	Rx1	Rx2	Rx3	Rx1	Rx2	Rx3
11/4/2016	5.7%	0.0%	0.0%	9.4%	9.3%	5.5%	9.4%	2.3%	16.4%
11/15/2016	0.0%	4.5%	0.0%	14.6%	20.5%	21.2%	12.5%	2.3%	7.1%
11/21/2016	3.2%	4.1%	0.0%	16.1%	12.2%	12.9%	16.1%	2.0%	7.1%
11/28/2016	2.3%	0.0%	0.0%	13.6%	8.9%	11.5%	13.6%	3.6%	12.8%
	Crawling Ciliates			**Stalked Ciliates**			**Metazoa**		
	Rx1	Rx2	Rx3	Rx1	Rx2	Rx3	Rx1	Rx2	Rx3
11/4/2016	0.0%	0.0%	1.8%	5.7%	30.2%	9.1%	69.8%	58.1%	67.3%
11/15/2016	2.1%	0.0%	2.4%	12.5%	18.2%	28.2%	58.3%	54.5%	41.2%
11/21/2016	0.0%	0.0%	0.0%	12.9%	12.2%	28.6%	51.6%	69.4%	51.4%
11/28/2016	0.0%	0.0%	0.0%	11.4%	19.6%	35.9%	59.1%	67.9%	39.7%

Sludge Volume Index

Sludge volume index (SVI) is an additional metric that can be monitored to characterize the health of wastewater sludge. SVI is the volume of solids that are occupied after a 30-minute settling period, in milliliters. Table 7 has general guidelines for the results from a SVI test.

TABLE 7: GENERAL GUIDELINES FOR SVI

SVI	Sludge Characteristic
< 80 mL/g	Dense with rapid settling. Old and potentially over oxidized sludge
100 to 200 mL/g	Good quality effluent. Medium settling, irregular flocs
> 250 mL/g	Slow settling, poor floc formation

The reactor fed with molasses for the first part of the study had a slightly higher SVI then SmartBOD. During the test good setability was noted with both reactors. However, after a slow increase in SVI, the SVI rapidly decreased to less than 100 mL/g. A dense mass was observed after the 30-minute settling period. During this same time, it was noted that during the MLSS testing for the reactor fed with molasses became difficult to filter. A possible cause for this is from the formation of filamentous bacteria. SmartBOD maintained a SVI in the ideal range of 100 to 200 mL/g for the duration of the study.

Ol' Roy dog food saw a continual increase in stability. Poor floc formation and poor settling were observed during testing. Table 8 and Figure 5 illustrate the SVI from the study.

TABLE 8: SLUDGE VOLUME INDICES.

	SVI (mL/g)		
Date	Molasses	Ol' Roy	SmartBOD
11/4/2016	217	363	157
11/7/2016	244	341	140
11/11/2016	230	397	157
11/16/2016	267	360	163
11/18/2016	263	457	170
11/21/2016	250	513	168
11/24/2016	150	553	137
11/28/2016	93	528	167
11/30/2016	70	619	158

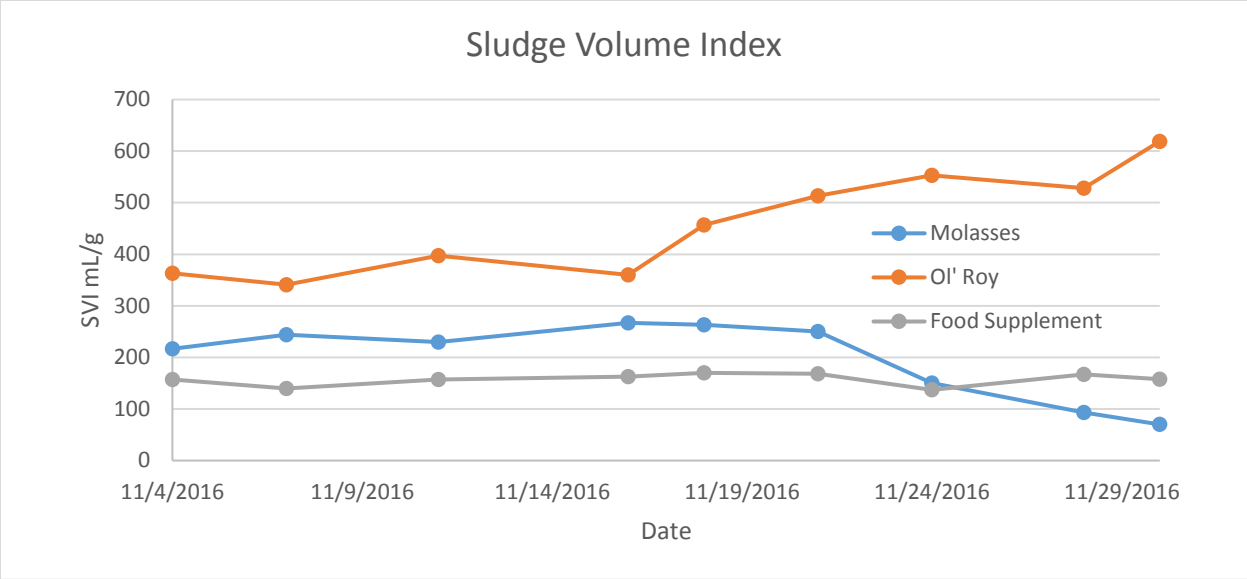

FIGURE 5: SLUDGE VOLUME INDICES.

Conclusion

The addition of SmartBOD as a food supplement (carbon source) outperformed molasses and Ol' Roy dog food when comparing the metrics of COD removal, nutrient accumulation and settling properties. The clearest advantage is when comparing it to the use of Ol' Roy dog food. The dog food reactor had high levels of solids, nutrient build up, and high levels of COD in the reactor effluent. All of these factors indicate that there was only partial treatment in the reactor containing the Ol' Roy dog food.

SmartBOD and molasses have similar levels of nutrient removal and a slightly less COD removal efficiency. The SmartBOD outperforms the molasses when it comes to the setability of the sludge. The SVI for the SmartBOD is right in the 'sweet spot' indicative of healthy sludge.

Concluding, the evidence from this study supports that the SmartBOD is a more efficient carbon source when compared to Old Roy dog food and molasses.