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Sampling Procedures for Piggery Slurry in Deep Pits for Estimation of Nutrient Content

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Accurate application rates of pig manure during pump out time depend on the correct determination of nutrient contents of the manure, which in turn is a function of the integrities of the samples or the sampling method. This study compared two sampling methods for obtaining representative samples from three different sources of manure prior to the actual pump out time from pig manure stored in pits, to a control method. In addition, empirical relationships between nutrients (nitrogen and phosphorus) and total solids that could help in quicker determinations of the manure nutrient contents on-site during scheduled pump out time were also investigated. Results showed that, stirring representative manure in a 200 *l* barrel for a period of at least 5 min using a paddle-stirrer such as the one described in this study is adequate for complete homogenisation of manure essential for drawing off a representative sample from any point in the barrel. Further, results showed that, the use of a sump pump (such as the one described in this study) placed at the bottom of a similar barrel and oriented to shoot manure horizontally is also adequate for homogenising the manure after 5 min of operation: a procedure that also allows for collection of a representative sample from any point in the container. Using the above two techniques, correct nutrient determinations are possible before the pumpout date, allowing for proper planning of the manure application in the field. The value for correlation coefficient R of 0·24 for a linear regression between total solids (TS) and total Kjeldahl nitrogen (TKN) using data obtained in this study was low suggesting that the content of TS cannot be used to estimate the TKN content. However, the value for the correlation coefficient R of 0·92 for a linear regression between TS and total phosphorus (TP) obtained using data from this study indicated that, TS can be used to estimate the TP in the manure.
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Introduction

The vast majority of manure management systems employed in pig production facilities in the state of Minnesota and other neighbouring states in the USA consist of collection and storage of liquid/slurry manure in pits. These pits are located either within or outside the production facilities. The designs of such stores differ in many respects: construction material, shape and size. In addition, manure slurries stored in these pits also vary in composition because of different feed rations, stage of growth of the pigs (piglets, sows, and fatteners) and the differences in management schemes. The net effect of the preceding scenarios is the uniqueness of each of all such manure holding pits.

Critical to accurate determination of manure application rates is undoubtedly the correct nutrient contents of the manure in question. In turn, the correct nutrient contents of the manure very much depend upon the integrities of the samples and the sampling methods. In practice today, nutrient contents of manure can be obtained from: (1) published values (ASAE, 1993; MWPS, 1985; Lorimor *et al.*, 1997; Campbell *et al.*, 1997; Killorn & Lorimor, 1999) based on average of manure samples from a particular region, (2) using some existing rapid methods (hydrometer method, ammonia electrode, water analysis field kits, and a 'Nitrogen Meter' that measures nitrogen gas pressure in a reaction chamber), or (3) analysis of manure samples in commercial analytical laboratories. The published

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Notation

K_1	numerical coefficient
K_2	numerical coefficient
N	total Kjeldahl nitrogen (TKN), $mg^{-1}l$
P	total phosphorus (TP), $mg^{-1}l$
R	correlation coefficient
R^2	coefficient of determination
S	total solids (TS), $g^{-1}l$
x	independent variable
y	dependent variable
$\acute{a}$	probability level of significance

values can be unreliable owing to the large variations in manure nutrients because of the factors mentioned in previous paragraph. Results from rapid methods have so far shown that although they can be used to provide acceptable nutrient estimates, they cannot replace laboratory analysis by approved standard methods (Chescheir *et al.*, 1985; Piccinini & Bortone, 1991). However, the commercial laboratory analyses of manure samples though more reliable involves waiting 1–2 weeks prior to getting the results, which is not practical since application must done immediately. This latter approach however, could, be feasible if the sampling could be done accurately 1–2 weeks prior to scheduled pumpout time so that the results are in hand during the pumpout time. Therefore, there is a need to continue to develop more innovative method(s) of manure sampling that ensures representative samples are obtained prior to pump out so that there is adequate time to do nutrient analyses at commercial laboratories before pump out time.

The problem of obtaining representative samples of manure either at the time of pump out or prior to the pump out time is generally well recognised not only because of the non-homogenous nature of the manure but also because of the tendency of manure to naturally stratify. There is increasing public concern of possible deleterious effects of farming on the environment reflected in new and impending federal and state legislation in the USA regarding farming operations. In a number of states or regions, pig producers are (will be) required to file comprehensive farm nutrient management plans with local authorities. These plans are designed to track the quantity of nutrients (primarily N and P) that are being imported onto and exported from each farm. To protect pig producers and also to enhance compliance, there exists an acute need for a reliable sampling and testing method to accurately determine the manure nutrients content prior to land application of manure. In areas where similar legislations are not in place, farmers must be encouraged to make better use of manure slurries, and therefore, reduce pollution risks. To encourage such practices, convenient and modest methods to accurately quantify the nutrients are necessary in order to spread these slurries efficiently and accurately in accordance with codes of good agricultural practice. These goals can be realised by either identifying and developing suitable sampling methods that would allow sufficient time to get back the analytical results from the commercial laboratory without delaying the pump out schedule or by providing some form of quick nutrient determination that can be used on-site during the scheduled pumpout time.

The objectives of this study were to: (i) evaluate two sampling methods that can be employed prior to pumpout to provide representative pig manure samples comparable to the samples obtained at pumpout when complete mixing is assumed, and (ii) determine an empirical relationship between the nutrients (N and P) and TS, which can quickly be determined using the hydrometer method on-site during scheduled pumpout time.

2. Materials and methods

2.1. *Sampling methods and sources of pig manure*

Manure slurries from three different sources (gestation, nursery, and finishing) were used to compare two envisioned sampling procedures to a procedure that is commonly used in the field (the control) to estimate nutrient content in the manure stored in deep pits. For the purpose of evaluating and/or comparing the above two method to the control, it was necessary to use same batch from each source to minimise variations in manure characteristics for a particular stage of the pig rearing period. Three farms from around Waseca County in Minnesota were randomly selected to represent pig manure at different pig rearing stages (gestation, nursery, and finishing). From each of these farms, enough manure to fill a 200 *l* barrel was obtained for the sampling study. To ensure adequate representation, the manure was drawn off by continuously and steadily lowering and raising the sump pump in the manure pits in a random manner in each case.

2.1.1. *Method I*

A schematic of the manure sampling device and the sampling locations (points) for method I, is shown in *Fig 1*. In this arrangement, a paddle-stirrer (1725 min^{-1}, 0·373 kW) was allowed to run for 5 min prior to sampling. This stirrer created a vertical and outward swirling mixing of manure. After this mixing period and

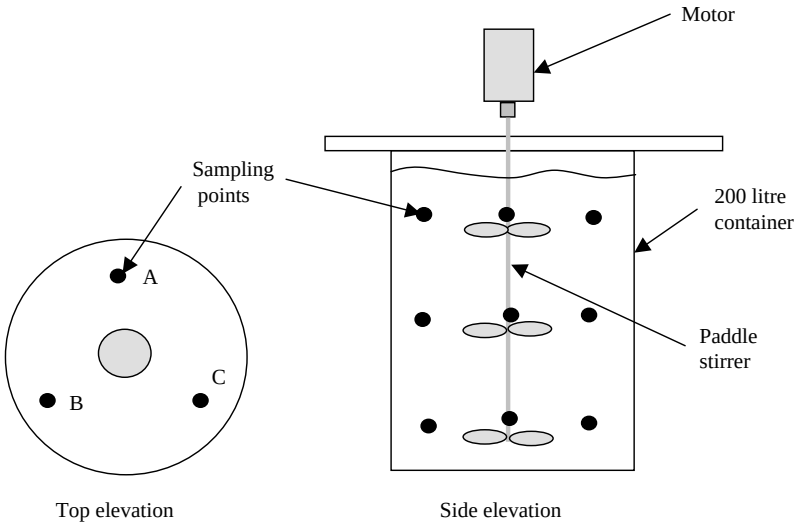

Fig. 1. Schematic of manure sampling device and sampling locations (container dimensions: height = 91 cm; diameter = 56 cm)

while still stirring the manure, approximately 100 m*l* samples were drawn off from top to bottom at 2·5 cm from top and bottom ends, and at mid-depth using a vacuum siphon. At each sampling depth, the manure was sampled at approximately the three points marked A, B, and C, equally spaced on an imaginary circle concentric with the barrel rim but leaving approximately 5·0 cm from the wall. These points had previously been marked on the manure container to provide a guide during sampling. Each run therefore resulted in triplicates samples for each depth and for each location. For the three pig manure slurry types, three runs with manure from the same manure batch/source resulted in nine samples at each depth, and nine samples for each lateral location, resulting in a total of 81 samples. Between runs, the barrels were refilled to the initial level to compensate for the samples drawn during the preceding run. The refill was done using a well-mixed sample initially drawn from a completely mixed larger volume of the same pig slurry.

2.1.2. *Method II*

The same setting as that used in method I was used except that, instead of using the paddle-stirrer to mixer the manure, a sump pump (0.25 kW, single-phase, 3.4 $l s^{-1}$ at 0.5 bar) sitting at the bottom of the container with the outgoing stream shooting horizontally was used to facilitate manure agitation. This agitation scheme closely simulated the common practice used by producers when emptying manure pits or other similar storages. After 5 min of manure agitation, the manure was sampled in exactly the same depths and lateral locations as in method I. Just as in method I, three runs with same batch of manure from each of the three different sources resulted in a total of 81 samples.

2.1.3. *Control method*

Again, the same setting as in the previous two methods was used except that after thoroughly mixing, the manure was left undisturbed for 5 h. Samples were then drawn off from the exactly the same depths and locations as in the previous two methods. This method simulates the sampling procedure in deep pits without agitation and has been preciously been investigated and recommended by various researchers (Campbell *et al.*, 1997; Lorimor & Kohl, 2000). It was therefore chosen to provide a baseline for evaluating the other two procedures.

2.2. *Laboratory analyses*

Although manure TS is the major factor governing the uniformity of the samples and therefore, the best indicator to determine if a method of sampling produces uniform or representative samples, manure nutrients [total Kjeldahl nitrogen (TKN) and total phosphorus (TP)] contents were also determined for a more thorough evaluation of the sampling procedures as well as to provide data for the determination of the empirical relationships between TS and the nutrients (N and P).

The following parameters were determined for each collected sample using standard laboratory methods (APHA, 1998): TS, TP and TKN. For determination of TS, a well-mixed sample was evaporated in a pre-weighed dish and dried to constant weight in an oven at 105°C. The increase in weight over that of the empty

dish represented the TS. Total phosphorus was determined using the persulphate digestion method. This is a method in which all the species of phosphorus in a sample are first converted to orthophosphates. The samples are then filtered and the phosphorus is measured quantitatively using the ascorbic acid method. Nitrogen (N) was determined as total Kjeldahl nitrogen (TKN) in which both organic nitrogen and ammoniacal nitrogen are converted to ammonium in the presence of concentrated H_2SO_4 and cupric sulphate ($CuSO_4$) catalyst. After addition of base, ammonia is distilled from an alkaline medium and absorbed in boric acid. The distilled ammonia is determined by titration with a standard mineral acid.

2.3. *Experiment design and statistical analyses*

To determine the homogeneity (or lack of homogeneity) of the samples obtained by each sampling method, TS, TP and TKN were measured at three depths and three lateral locations for each of the manure collected from the gestation, finishing, and nursery, at three replications, for each method. This is a typical four-factor factorial design (sampling method, source of manure, depth, and lateral location) with three replicates and was the model used to perform analyses of variance on the responses (TS, TKN, and TP). In addition to this, each method was individually evaluated with respect to manure for the three sources on the basis of uniformity of samples with respect to depth of sampling and location of sampling. Analyses of variances (ANOVA) were performed using standard computer-based statistical analysis software, widely known as SAS (SAS Institute Inc., 2000). Unless otherwise stated statistical significance is implied at the 5% significance level.

3. Results and discussion

3.1. *Evaluations of the sampling methods*

The summary of the statistics of TS, TKN, and TP of the samples obtained with each of the three different methods at the three different depths and lateral locations for the three different sources of manure are presented in Tables 1–6. The results of solids and nutrients of samples obtained using method I, are presented in Tables 1 and 2 by depth and lateral location, respectively. The results obtained by method II are shown in Tables 3 and 4, while the results obtained from the control are shown in Tables 5 and 6. Apart for sampling by the control, the results of N and P obtained by the two methods are not significantly different with either the depth or lateral location of sampling. A significantly more TS observed in the samples drawn off at the top using method I for the manure obtained from the nursery may possibly be attributed to the errors in the laboratory determinations of TS because the sampling does not have any significant effect on the nutrients determinations. These results suggest that, as long as at least 5 min mixing or agitation period is allowed prior to sampling using the mixing/agitation equipment similar to the one used in this study, a representative sample can be drawn just about anywhere in this or a similar container for nutrient determination.

Table 1
Summary statistics of sampling by depth using method I for total solids (TS), total Kjeldahl nitrogen (TKN), and total phosphorus (TP)

Growing stage of pigs	*Sampling depth*	*Samples parameter means* (sample size n = 9)*		
		TS, gl^{-1}	*TKN, mgl^{-1}*	*TP, mgl^{-1}*
Finishing	Top	35·93[a]	5966[a]	1081[a]
	Middle	36·01[a]	6024[a,b]	1110[a]
	Bottom	36·03[a]	6068[a]	1123[a]
Gestation	Top	27·78[a]	3770[a]	899[a]
	Middle	27·28[a]	3711[a]	903[a]
	Bottom	27·23[a]	3712[a]	884[a]
Nursery	Top	70·27[a]	4751[a]	1639[a]
	Middle	69·43[a,b]	4805[a]	1664[a]
	Bottom	68·02[b]	4763[a]	1662[a]

Means with the same letter in the same column and within the same type of pigs are not significantly different at the probability level $\alpha = 0{\cdot}05$.
*These are means of three samples taken at three different locations in three consecutive runs.

Table 2
Summary statistics of sampling by location using method I for total solids (TS), total Kjeldahl nitrogen (TKN), and total phosphorus (TP)

Growing stage of pigs	*Location*	*Samples parameter means* (sample size n = 9)*		
		TS, gl^{-1}	*TKN*, mgl^{-1}	*TP*, mgl^{-1}
Finishing	A	36·06[a]	6009[a]	1100[a]
	B	35·08[a]	6041[a]	1095[a]
	C	36·11[a]	6008[a]	1119[a]
Gestation	A	27·48[a]	3741[a]	904[a]
	B	27·22[a]	3712[a]	890[a]
	C	27·59[a]	3740[a]	891[a]
Nursery	A	70·70[a]	4756[a]	1658[a]
	B	68·39[b]	4784[a]	1665[a]
	C	68·63[b]	4778[a]	1643[a]

Means with the same letter in the same column and within the same type of pigs are not significantly different at the probability level $\alpha = 0{\cdot}05$.
*These are means of three samples taken at three different depths in three consecutive runs.

Table 3
Summary statistics of sampling by depth using method II for total solids (TS), total Kjeldahl nitrogen (TKN), and total phosphorus (TP)

Growing stage of pigs	*Sampling depth*	*Samples parameter means* (sample size n = 9)*		
		TS, gl^{-1}	*TKN*, mgl^{-1}	*TP*, mgl^{-1}
Finishing	Top	37·31[a]	6078[a]	1108[a]
	Middle	37·05[a]	6053[a]	1218[a]
	Bottom	37·21[a]	6110[a]	1093[a]
Gestation	Top	26·37[a]	3767[a]	780[a]
	Middle	26·26[a]	3771[a]	821[a]
	Bottom	26·10[a]	3665[a]	805[a]
Nursery	Top	69·82[a]	4748[a]	1617[a]
	Middle	69·85[a]	4822[a]	1640[a]
	Bottom	70·66[b]	4856[a]	1638[a]

Means with the same letter in the same column and within the same type of pigs are not significantly different at the probability level $\alpha = 0{\cdot}05$.
*These are means of three samples taken at three different locations in three consecutive runs

The control method depicts typical stratification of the manure in holding or storage pits especially with respect to the manure slurries from the gestation barn (Table 5). This natural stratification of the manure is not observed in the manure from the nursery-barn pit and only moderate stratification is observed in the manure from the finishing barn. The authors believe that the manure slurry obtained from the nursery-barn (approximately 6.9% solids) and the finishing barn (approximately 3.6%) was perhaps too thick to significantly stratify during the 5 h of quiescent settling. This observation agrees with previous research (Ndegwa *et al.*, 2002), which showed that, solid sedimentation decreased with increasing solid content from approximately 66% to only 8% effective sedimentation at 1 and 6% TS, respectively. Based on this observation, it can be inferred that, for such thick manure slurries and within 5 h of agitation, representative manure samples can be obtained at any point at any time. Although this finding may not be important for the purpose of manure sampling (no need for such long delays after agitation before collecting samples), it is very important in mixed reactors design and operations where complete mixing is desired over the reaction periods during treatment of pig manure. However, more work is necessary to further validate this postulation.

The effect of settlement (as illustrated by the control method) has been studied in the past for manure

Table 4
Summary statistics of sampling by location using method II for total solids (TS), total Kjeldahl nitrogen (TKN), and total phosphorus (TP)

Growing stage of pigs	*Location*	*Samples parameter means* (sample size n = 9)*		
		TS, gl^{-1}	*TKN*, mgl^{-1}	*TP*, mgl^{-1}
Finishing	A	36·87[a]	6076[a]	1100[a]
	B	37·28[a]	6081[a]	1221[a]
	C	37·41[a]	6084[a]	1097[a]
Gestation	A	26·55[a]	3761[a]	833[a]
	B	25·78[a]	3770[a]	811[a]
	C	26·40[a]	3772[a]	762[a]
Nursery	A	69·81[a]	4793[a]	1643[a]
	B	69·70[a]	4804[a]	1635[a]
	C	70·81[a]	4828[a]	1618[a]

Means with the same letter in the same column and within the same type of pigs are not significantly different at the probability level $\alpha = 0{\cdot}05$.
These are means of three samples taken at three different depths in three consecutive runs.

Table 5
Summary statistics of sampling by depth using method III for total solids (TS), total Kjeldahl nitrogen (TKN), and total phosphorus (TP)

Growing stage of pigs	*Sampling depth*	*Samples parameter means* (sample size n = 9)*		
		TS, gl^{-1}	*TKN*, mgl^{-1}	*TP*, mgl^{-1}
Finishing	Top	28·63[a]	5918[a]	677[a]
	Middle	33·22[b]	6140[b]	897[b]
	Bottom	34·50[c]	6194[b]	955[c]
Gestation	Top	11·85[a]	2998[a]	212[a]
	Middle	11·54[a]	2979[a]	189[a]
	Bottom	39·68[b]	4563[b]	1224[b]
Nursery	Top	67·36[a]	4817[a]	1522[a]
	Middle	67·87[a]	4891[b]	1485[a]
	Bottom	67·86[a]	4883[a,b]	1536[a]

Means with the same letter in the same column and within the same type of pigs are not significantly different at the probability level $\alpha = 0{\cdot}05$.
*These are means of three samples taken at three different locations in three consecutive runs.

sampling. Lorimor and Kohl (2000) compared the means of TKN and TP of a vertical profile with the means of top, middle and bottom samples of several pits in Iowa and found that, while TKN values were not significantly different, the TP values were significantly different. Further, they observed that unagitated vertical profile samples were not significantly different from samples taken during the complete agitation for TS, TP except TS. Campbell *et al.* (1997) on the other hand noted that, compared to a composite sample of top, mid-depth, and bottom of the pits, the mid-depth sample generally represented the average manure nutrient concentration in the storage. Since it is reasonable to expect the manure homogenised by mixing or agitation to give more accurate results irrespective of the depth or location of sampling as is observed in this study with respect to methods I and II, then, from the data obtained in this study, the means of top, mid-depth and bottom samples are found to underestimate the TS and TP. The authors believe this happens because the sludge occupies a smaller depth or volume of the total depth or volume, *i.e.* the top and the mid-depth samples are likely to come from above the sludge thus skewing the effective TS and TP towards these lower values. On the other hand, since most of the TKN is perhaps in solution, the settling of the solids do not skew the means towards either top or bottom. Although Lorimor and Kohl (2000) and Campbell *et al.* (1977) procedures can be

Table 6
Summary statistics of sampling by location using method III for total solids (TS), total Kjeldahl nitrogen (TKN), and total phosphorus (TP)

Growing stage of pigs	*Location*	*Samples parameter means* (sample size n = 9)*		
		TS, gl^{-1}	*TKN, mgl^{-1}*	*TP, mgl^{-1}*
Finishing	A	31·90[a]	6068[a]	858[a]
	B	32·41[a]	6102[a]	830[a]
	C	32·04[a]	6082[a]	841[a]
Gestation	A	20·63[a]	3483[a]	547[a]
	B	21·88[a]	3533[a]	557[a]
	C	20·56[a]	3523[a]	519[a]
Nursery	A	68·69[a]	4850[a]	1539[a]
	B	67·54[a,b]	4864[a]	1512[a]
	C	66·86[b]	4878[a]	1492[a]

Means with the same letter in the same column and within the same type of pigs are not significantly different at the probability level $\alpha = 0{\cdot}05$.
*These are means of three samples taken at three different depths in three consecutive runs.

used to provide acceptable estimates of nutrients (TKN and TP), they are more likely to underestimate the TP compared to the complete mixing of manure described in this study.

3.2. *Relationships between total solids, total Kjeldahl nitrogen, and total phosphorus*

The relationships between nutrients: TKN and TP, and TS are shown in *Figs 2* and *3*, respectively. These plots were made using the consolidated data obtained in this study (sample size $n = 241$). Since previous research (Ndegwa *et al*., 2002; Tunney, 1969; Dragun, 1978; Chescheir *et al*., 1985; Piccinini & Bortone, 1991; Scotford *et al*., 1998) indicated linear relationships between the nitrogen and phosphorus in the manure, linear regressions relationships were chosen to enable comparison with previous studies. As noted above, there is little correlation between TS and TKN ($R = 0{\cdot}24$) while a high correlation of TP against TS ($R = 0{\cdot}92$) is observed. In *Fig. 2*, it is quite apparent that, the TKN values were easily separable by the source of manure and the correlations between TKN and TS were poor except for the manure from the gestation barn. The TKN in the manure from the latter barn correlated fairly well ($R^2 = 0{\cdot}95$) with the TS while the TKN in the manure from the former barns remained more or less constant within the narrow TS ranges.

Regression analyses of TS on TKN and TP obtained in this study as well as other comparable regression equations of TS on TKN and TP from literature has been summarised in Table 7. For easier comparisons, these regression equations have also been further plotted

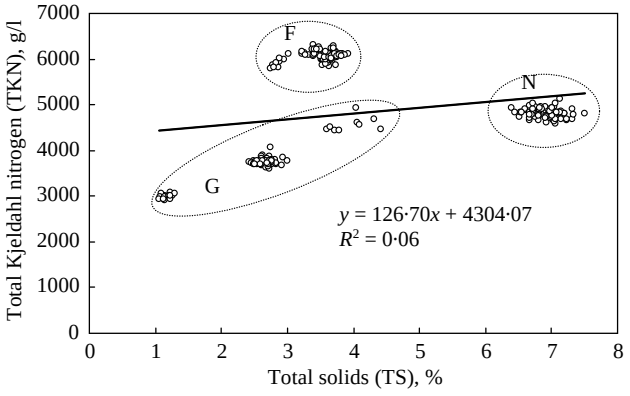

Fig. 2. Linear correlations between total Kjeldahl nitrogen (TKN) and total solids (TS) for the consolidated data; N, nursery; G, gestation; & F, finishing; R^2, coefficient of determination

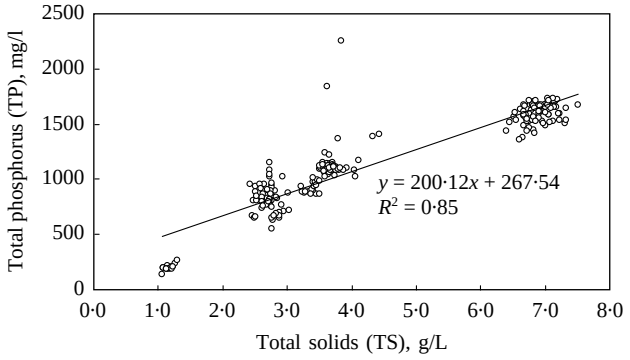

Fig. 3. Linear correlations between total phosphorus (TP) and total solids (TS) for the consolidated data (nursery, gestation, and finishing); R^2, coefficient of determination

Table 7
Regression equations for total solids (TS) against total Kjeldahl nitrogen (TKN) and total phosphorus (TP) from existing literature and this study

Related parameter	*Regression equation* ($N = K_1 + K_2 S$)*	*Regression coefficient* (R)	*Source*
TS versus TKN	$N = 1194 + 424\ S$	0·92	Tunney (1979)
	$N = 3753 + 186\ S$	0·28	Literature†
	$N = 362 + 598\ S$	0·95	Dragun (1978)
	$N = 2433 + 396\ S$	0·88	Chescheir et al. (1985)
	$N = 1095 + 600\ S$	0·90	Piccinini and Bortone, (1991)
	$N = 3363 + 415\ S$	0·95	Ndegwa et al. (2002)
	$N = 4261 + 136\ S$	0·24	Current study
TS versus TP	$P = -117 + 232\ S$	0·92	Tunney (1979)
	$P = 305 + 186\ S$	0·75	Literature†
	$P = 112 + 239\ S$	0·94	Dragun (1978)
	$P = -112 + 334\ S$	0·77	Chescheir et al. (1985)
	$P = 26 + 269\ S$	0·84	Scotford et al. (1998)
	$P = 320 + 312\ S$	0·88	Piccinini and Bortone, (1991‡)
	$P = 264 + 383\ S$	0·85	Ndegwa et al. (2002)
	$P = 200 + 267\ S$	0·85	Current study

*Compiled by Chescheir et al. (1985) from other literature sources.
†N is the TKN in ppm; P is the TP in ppm, S is the TS as a %; K_1 and K_2 are two coefficients.
‡Converted from different units by the authors.

on the same axes in *Figs 4* and *5* for TKN and TP, respectively. Clearly, the regression equations of TS on TKN compiled by Chescheir *et al*. (1985) from various literature sources and that obtained in this study compare favourable but both are substantially low compared to others found in the literature. However, even though correlation coefficients of regression equations between TS and TKN or between TS and TP obtained in those other studies compare well with each other, it is obvious that the absolute terms as defined by the coefficients K_1 and K_2 in all the regression equations are as varied as the authors. These differences are not surprising given the dynamic changes in pig diets over the years, different diets in different countries, different diets for different ages of pigs, and finally the different management systems of both the pigs and the slurries. For these kinds of data to be useful, a complete description of the slurries with regard to all the aforementioned parameters needs to be given each time so that data from similar sources can be compared or consolidated to provide more accurate regression equations for specific situations. In most of the cases, this information is not provided. In view of this, no individual empirical equation(s) can be recommended as a representative for accurate estimates of nutrients in the pig manure slurries based on only the analysis of TS of manure. However, for individual production facilities, with more or less unchanging pig/piglets diet and unchanging other facility management schemes, such empirical relationships could be established and subsequently used to estimate nutrients levels in future manure slurries. More work is recommended to verify this postulation.

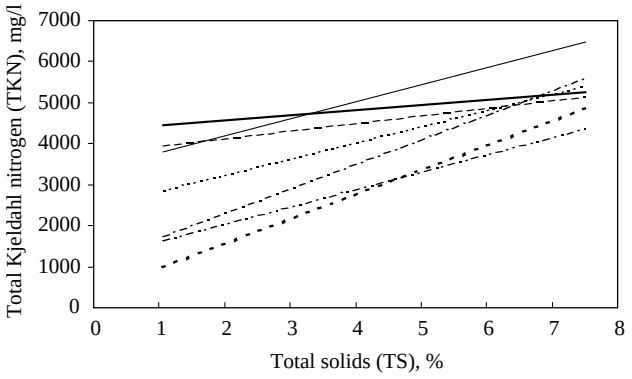

Fig. 4. A comparison of linear regression equations for total solids (TS) against total Kjeldahl nitrogen (TKN) from existing literature and this study: ——, current study; ——, Ndegwa et al.; - - - -, Literature; ·····, Chescheir et al.; -·-·-, Piccinini & Bortone; -··-··-, Tunney; ·····, Dragun*

3.3. *Methods use at farm level*

Both methods I and II can be used on the farm to help in getting representative samples prior to scheduled pumpout time. The buildings with under-the-slat deep pits usually have pump out side-pits located conveniently projecting outside the building. The authors envisage the use of similar barrels without bottoms that

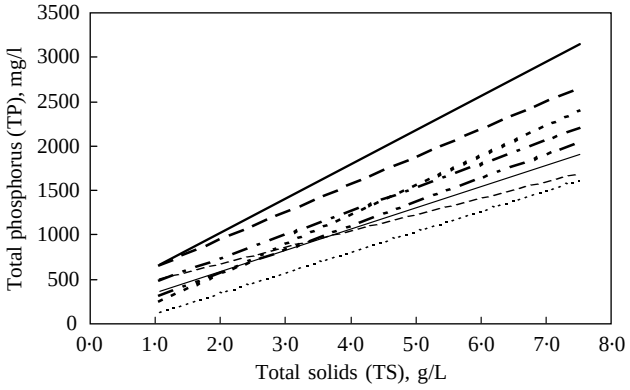

Fig. 5. A comparison of linear regression equations for total solids (TS) against total phosphorus (TP) from existing literature and this study: ——, Ndegwa et al.; – – – –, Piccinini & Bortone; ·····, Chescheir et al.; –·–·–, Current study; –·····–, Scotford et al.; ——, Dragun; – – – –, Literature; ·····, Tunney*

can be placed in the pump out side-pits to curve out or separate limited quantities of manure for agitation with either of the two devices described in this study. Alternatively, a removable gate can be incorporated on the fourth side of these pump out side-pits to cut off the manure held within the pump out side-pits and agitation of manure so held can then be ensured using method I and II described in this study. This way, representative samples can be obtained without agitation of the entire pit but just by agitating smaller portions of manure in those pump out side-pits that represent the manure in the respective larger pits.

4. Conclusions

(1) Stirring representative manure in a 200 *l* barrel for a period of at least 5 min using a paddle-stirrer such as the one described in this study is adequate for complete homogenisation of the manure. This implies that a representative sample of the manure in question can be drawn off from any point in the barrel.

(2) The use of a sump pump (such as the one described in this study) placed at the bottom of a similar barrel and oriented to shoot the manure horizontally is also adequate for homogenising the manure after 5 min of operation. This procedure, therefore, also allows for collection of a representative sample from any point in the container.

(3) Using the above two techniques and the envisaged uses at the farm level described in the results and discussion section, correct nutrient determinations may be possible before the pumpout date without expensive agitation of entire pits, allowing for proper planning of the manure application in the field. Further studies of the actual methods use at the farm level, however, are recommended for verification of this vision.

(4) The correlation coefficient ($R = 0{\cdot}24$) of a linear regression between total solids (TS) and total Kjeldahl nitrogen (TKN) using data obtained in this study was low. This result suggests that the content of TS cannot accurately be used to estimate the content of the TKN. This result contradicts most earlier research findings. The correlation coefficient ($R = 0{\cdot}92$) of a linear regression between TS and total phosphorus (TP) obtained using data from this study indicates that, the content of TS can be used to accurately estimate the content of TP. This result is corroborated by numerous past research findings.

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