Dry Matter Density and Relative Feed Value of a Sensor Developed by Harvest Tec

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Introduction

Harvest Tec (Hudson, WI) has developed a sensor, which attaches to a baler, and is then designed to measure moisture %, acid detergent fiber % (ADF) and neutral detergent fiber % (NDF) of hay as it is baled. These two values are then be used to determine the relative feed value (RFV) for each bale of hay. An additional piece of equipment can also be attached to the baler that gives the weight of each bale. These pieces of information are entered onto an RFID tag that is attached to the bale. In addition, the location of the field from which the bale came from can be added to the tag. A hand-held or stationary scanner is then used to read the information on each tag. Having this information at the time of baling can save time and money in terms of sampling costs and provides real-time information for the buyer or seller. The purpose of this project was to compare scissor clipped samples from each field (essentially this is the control) with laboratory analysis of each bale, by field and cutting, to help develop and calibrate the sensor to give accurate results in the field.

Material and Methods

This project was carried out on farms owned and operated by Utah State University Agricultural Experiment Station. Hay samples from 3 fields over 3 cuttings (546 total bales) were used for this project. On the day of cutting, scissor samples were collected at different locations within the field, composited, and then taken to the USU Analytical Laboratory for compositional analysis. The scissor cuts were taken to mimic the height of the cutting bar to give representative samples. For most fields and cuttings, one sample was used to compare with the laboratory samples; however, there were two fields that had 3 and 5 samples taken. These were used to compare statistical differences and extrapolated back to the laboratory samples. Bales from these fields were then sampled and analyzed at the same laboratory to give the hay composition. These values were averaged and compared with the scissor cut sample(s).

Results

Analysis of the scissor cut samples are shown in Table 1. Only averages for Field 1&2 – 1 (n = 3) and Field 10 – 3 (n = 5) are shown. All others represent one value. Table 2 shows the averages of the laboratory analysis for samples taken from bales based on field and cutting. The values are graphed and shown in Figures 1 to 5. The most obvious difference is in moisture %. This is to be expected and will be discussed later. Figures 6 – 9 are statistical comparisons using Field 10 – 3 because there were 5 scissor samples. Because of multiple samples, standard deviations could be compared. There were 49 laboratory samples. A t-test (Two samples assuming unequal variance) was performed on each of the 4 different composition variables. All were significantly different except for ADF%. Even though significantly different, from a practical aspect, the differences were minor. One field was chosen to show the individual variation between bales for one parameter of interest. Figure 10 shows the RFV for all bales from one field for one specific cutting. Any field could have been chosen and would have shown similar variation. For this one field the mean was 184 and ranged from an RFV of 140 to 232. The important point is that all bales from a field are not uniform and sampling can be a great source of variation (and possibly contention) if too few samples are taken to give a uniform sample for analysis.

A subset of the total bales was pair matched to compare the sensor moisture % against the laboratory analysis moisture %. The results are shown in Table 3. The correlation, as we expected, was very low (Figure 11). We recognize that the laboratory samples are going to be more uniform and drier than the bale moisture because of the sample processing used prior to laboratory analysis. The purpose was to try and develop some type of correction factor that could be used to come up with a more realistic dry matter value in the field. Baler moisture percent was corrected based on the mean and standard deviation of the baler moisture content for the 383 samples. Therefore the baler moistures were adjusted by the following correction factors: if moisture was <8.21%, then 0.93 was subtracted from the original baler moisture %; if <12.51, then 0.98 was subtracted; if <16.81, then 1.03 was subtracted; if anything was over 16.81, then 1.08 was subtracted. The results of the correlation between the dry matter of a bale based on laboratory analysis and the dry matter of a bale based on the corrected moisture from the sensor are shown in Figure 12. While not perfect, it shows an improvement in the R^2 value and may be useful in giving more realistic values of actual bale weight on a dry matter basis. Correction for size of bale based on cubic feet and cubic feet of dry matter probably won't improve the value because multiplying by a constant doesn't change the relative difference between bales. We could not find an acceptable way of correcting our data set for moisture or density that would provide an acceptable estimate of RFV. It appears that will have to come from the laboratory analysis.

Additional figures are listed showing relationships between different compositional variables that may be of interest in the future. They are: Figure 13 (ADF% compared with NDF% of bale samples based on laboratory analysis); Figure 14 (RFV compared with NDF%, ADF% and CP% in bale samples based on laboratory analysis); Figure 15 (RFV compared with NEL in bale samples based on laboratory analysis); Figure 16 (RFV compared with TDN% of bale samples based on laboratory analysis); and Figure 17 (NDF% compared with CP%, by cutting, based on laboratory analysis).

Discussion and Recommendations

1. Using the scissor cut method is a reasonable way to get information for calibrating the sensor on the baler. Based on the overall averages for all fields and all cuttings, all composition values were within normal ranges of variation and analytical techniques. The differences between CP%, ADF% and NDF% were 1.3%, 0.8% and 0.1%, respectively. The RFV was ~ 2 units different. These are all significantly less than the standard deviations of the laboratory results for these same variables (1.4%, 2.4% and 3.0%, respectively). The standard deviation for RFV was 19.8 units. This is interesting because the range in values, using the same sample, for this laboratory is approximately 3.5, 2.1 and 3.5%, respectively (results from an unrelated project). However, there is a certain amount of built-in variation within the whole system that needs to be kept in mind such as sampling variation, laboratory variation and within field variation (Fig. 10). The "big picture" is that this is a reasonable method of calibration. I would recommend that multiple (at least 3) field samples be collected and averaged for the calibration in order to

help watch for and deal with field variation. Another aspect to consider would to collect "scissor" samples by taking several grab samples of the new mown hay immediately after cutting rather than clipping samples prior to cutting. In my opinion, you would get the same results.

2. There are large variations in the moisture % of the bale as it comes off the baler. These do not correlate with laboratory moisture contents. This is to be expected because the laboratory samples are dried prior to analysis. Because of this variation, the "in field" dry matter in a bale could be misleading and not be a true reflection of the actual dry matter. This may reflect "real life" issues of buying and selling hay and probably over or under estimate the true dry matter in a bale in the field because hay is bought or sold based on actual weight. Therefore, an effort was made to try and correct the bale dry matter to closer reflect the actual dry matter based on laboratory moisture. This was moderately successful, but still only explains ~51% of the variation (this is an improvement from 25%; Figs. 11 vs 12).

3. Other relationships, based on the laboratory analysis of the samples are shown for the purpose of providing information that might be useful for incorporation of future information into the RFID tag.

4. As a final comment, the system seems to work and appears to be a practical way to get a reasonable approximation of the quality of hay as it comes out of the field. Because of the variation, I would suggest that there still needs to be some type of process to regularly calibrate the sensor so that it gives values representative of the hay in question. The system seems to work well under Utah conditions, using alfalfa hay, but we didn't test the system using grass hays or silages. I think that would be the next step in this process.

Table 1. Scissor clip values by field and cutting for 2013. Field 1&2 – 1 has 3 samples and Field 10 – 3 had 5 samples, but only the averages are shown here.

FIELD	Moist. %	Bale Weight	CP%	ADF%	NDF%	TDN%	RFV
Field 1&2 - 1st	5	1466	22.7	28.2	33.0	68.6	188.9
Field 1&2 - 2nd	9	1299	19.9	33.0	39.9	N/A	147.5
Field 1&2 - 3rd	8	1432	25.5	26.1	29.7	70.7	214.7
Field 7 - 1st	10	1577	21.7	26.7	33.0	70.1	191.8
Field 7 - 2nd	12	1424	19.6	32.1	39.3	N/A	151.3
Field 7 - 3rd	17	1404	20.7	30.9	37.6	65.7	160.3
Field 8 - 2nd	5	1245	20.7	28.0	35.5	N/A	176.1
Field 8 - 2nd	5	1245	21.7	24.4	31.0	N/A	209.7
Field 8 - 3rd	10	1417	21.1	30.3	36.3	68.0	167.4
Field 10 - 1st	11	1644	23.3	26.0	31.7	70.9	201.7
Field 10 - 2nd	15	1387	21.4	30.2	36.9	N/A	165.0
Field 10 - 3rd	12	1392	22.3	29.6	36.8	67.1	166.8
Total/Avg	**10**	**1415**	**21.8**	**28.7**	**34.9**	**68.8**	**179.5**

Table 2. Average values, based on laboratory analysis, of each bale by field and cutting for 2013.

Field	No. samples	DM %	Moisture %	CP %	ADF %	NDF %	RFV	Bale Weight
CJ-1&2	123	92.9	7.1	20.5	28.7	33.2	187.3	1406
CJ-10	8	92.5	7.5	20.7	26.6	31.3	205.0	1513
CJ-7	37	91.2	8.8	21.2	26.8	31.6	201.1	1492
Cutting 1 - Total/Avg	*168*	*92.5*	*7.5*	*20.7*	*28.2*	*32.8*	*191.2*	*1428*
CJ-1	78	93.5	6.5	19.7	32.3	38.1	156.5	1310
CJ-10	46	91.8	8.2	21.4	29.1	35.4	174.5	1398
CJ-7	18	92.4	7.6	20.1	32.1	38.1	157.5	1402
CJ 8A	24	93.1	6.9	18.3	30.6	38.1	159.9	1388
CJ 8B	2	92.5	7.5	22.0	24.5	29.1	223.0	1565
Cutting 2 - Total/Avg	*168*	*92.8*	*7.2*	*20.0*	*31.1*	*37.3*	*162.8*	*1358*
CJ-1&2	109	92.2	7.8	21.2	28.8	33.8	183.6	1465
CJ-10	49	92.2	7.8	20.7	29.3	34.7	177.5	1412
CJ-7	37	92.4	7.6	20.2	29.6	35.1	175.0	1453
CJ 8A	15	92.6	7.4	18.2	30.6	38.2	159.2	1461
Cutting 3 - Total/Avg	*210*	*92.3*	*7.7*	*20.7*	*29.2*	*34.6*	*178.9*	*1450*
Overall Total/Avg	**546**	**92.5**	**7.5**	**20.5**	**29.5**	**34.8**	**177.7**	**1415**

Table 3. Average and SD of moisture % based on laboratory analysis compared with baler reading. Values were obtained using bale identification number and match from the two lists.

Field	No. samples	Lab Moist. %	Lab SD	Baler Moist. %	Baler SD
CJ 8A	23	6.9	0.95	15.8	13.32
CJ-1	78	6.5	0.38	9.5	3.64
CJ-10	127	8.0	0.30	13.4	3.30
CJ-7	47	7.7	0.41	16.2	2.97
CJ-1&2	108	7.8	0.84	13.5	6.88
Total/Avg	**383**	**7.5**	**0.80**	**13.1**	**5.93**

Figure 1. Moisture % of samples based on laboratory analysis and scissor cut by field and cutting.

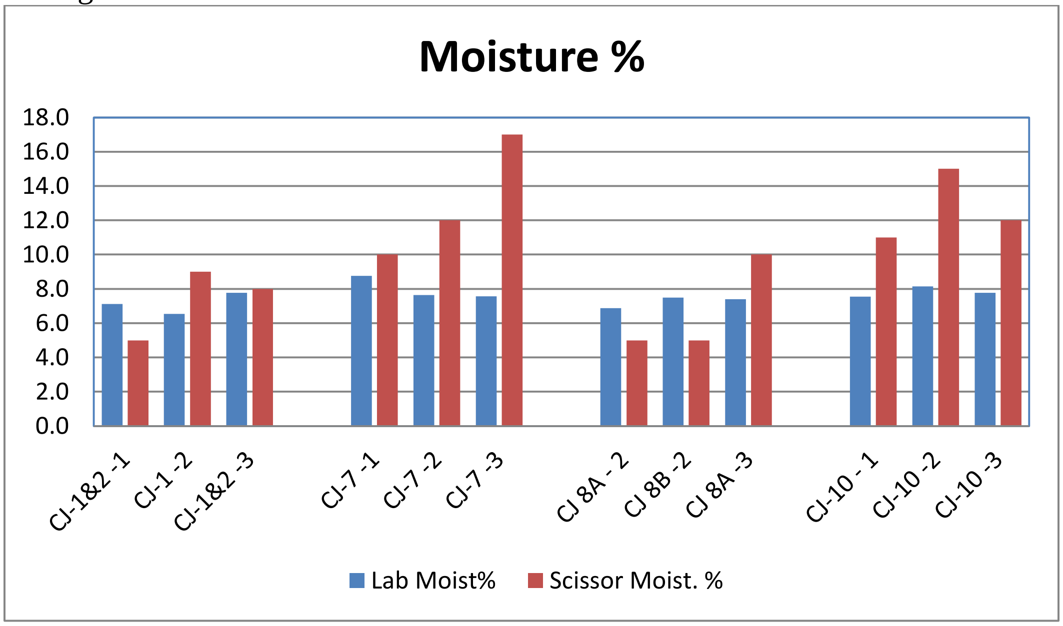


Figure 2. Crude protein % of samples based on laboratory analysis and scissor cut by field and cutting.

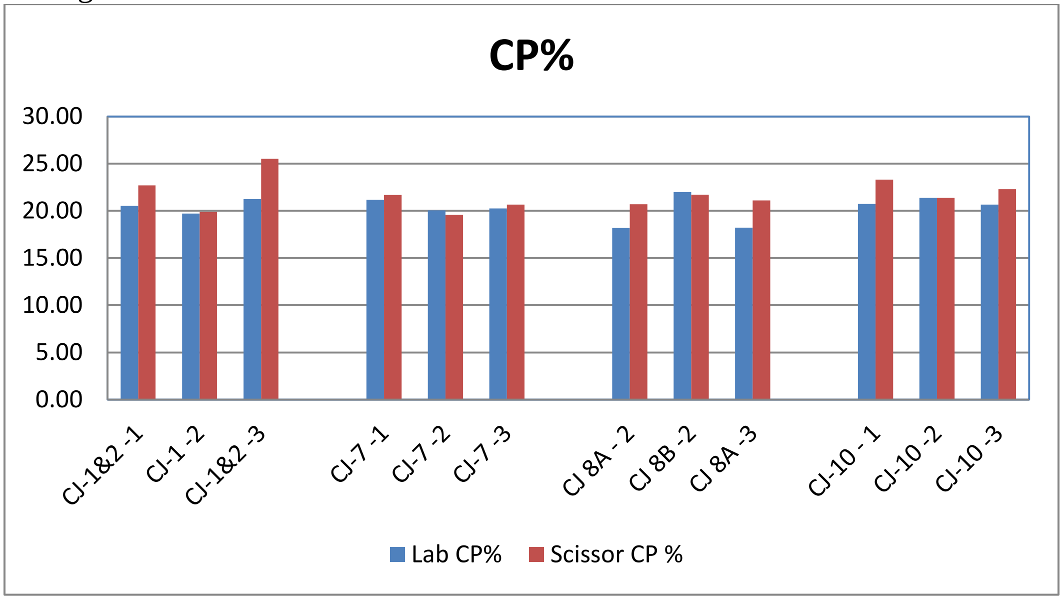


Figure 3. Acid detergent fiber % of samples based on laboratory analysis and scissor cut by field and cutting.

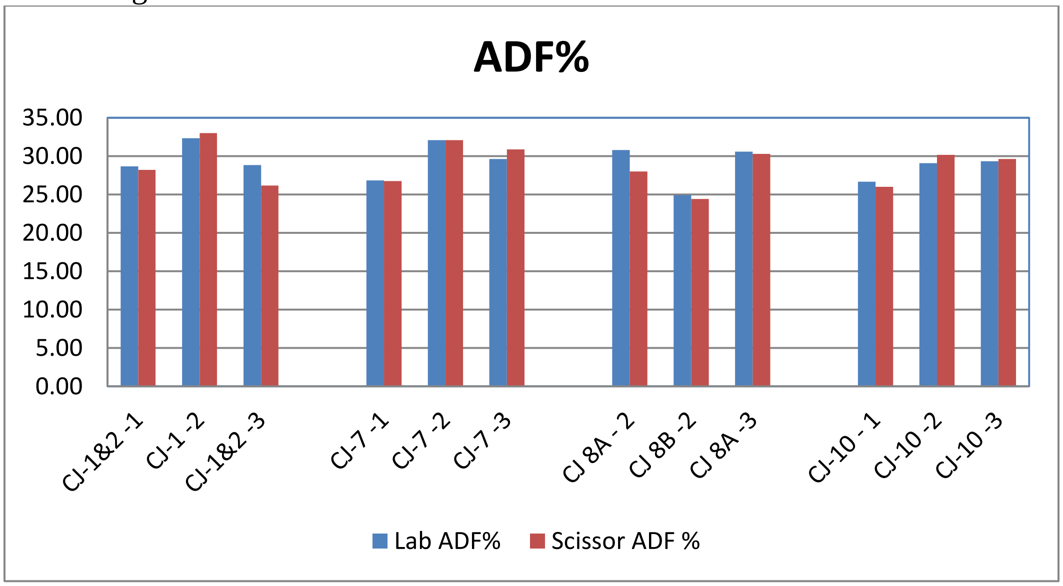


Figure 4. Neutral detergent fiber % of samples based on laboratory analysis and scissor cut by field and cutting.

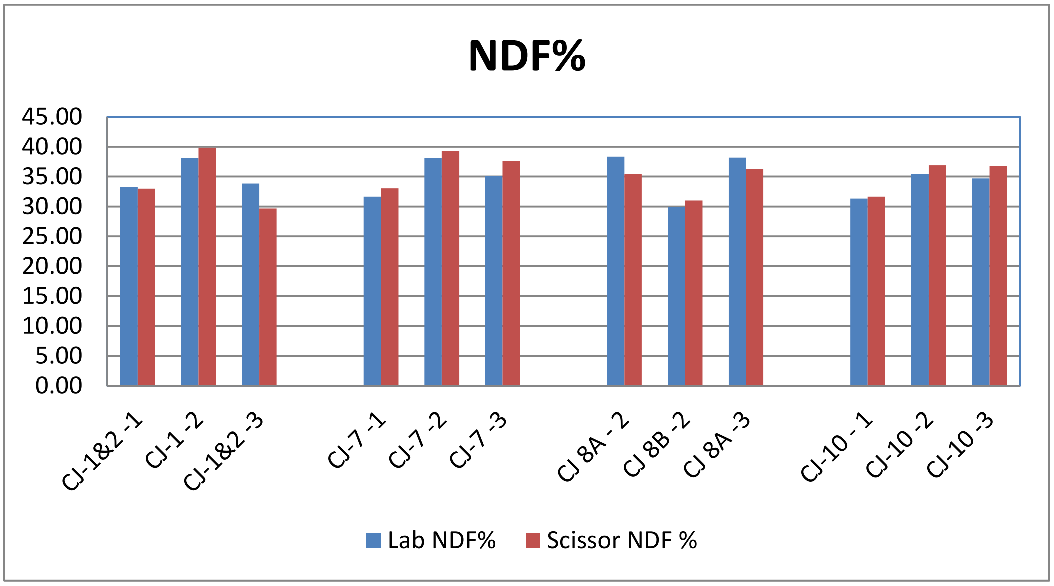
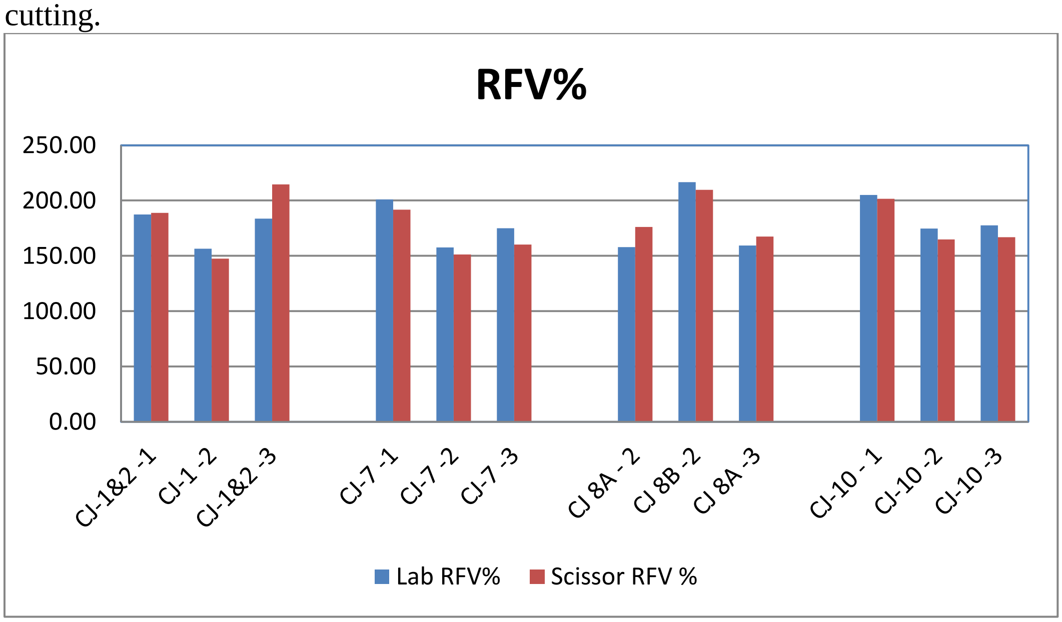
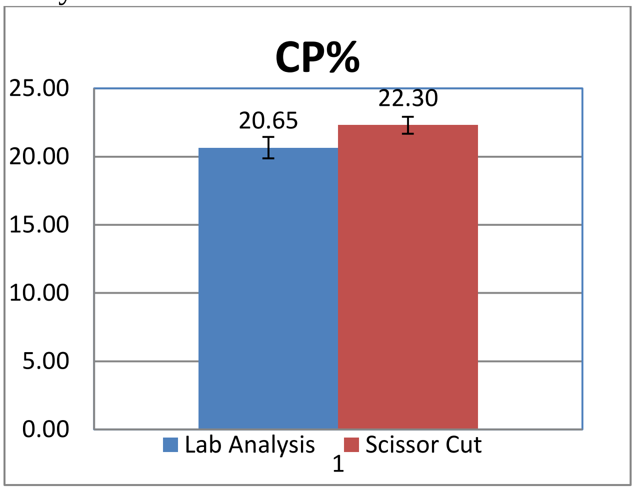
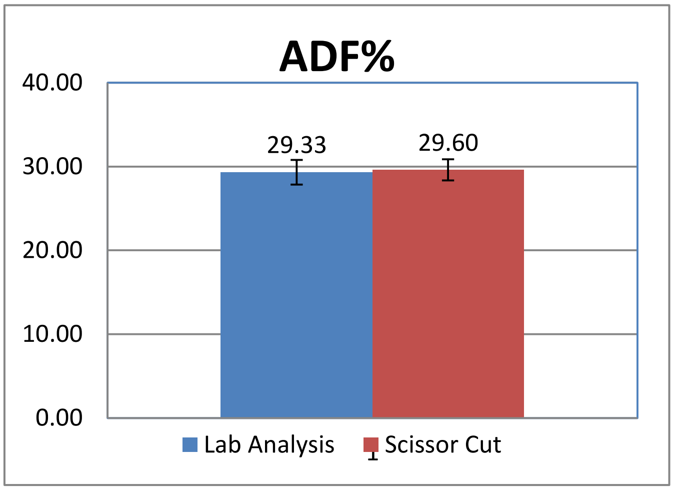


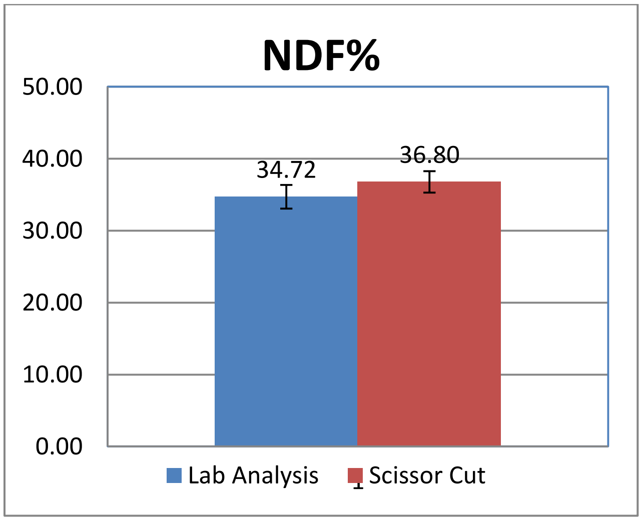
Figure 5. Relative feed value of samples based on laboratory analysis and scissor cut by field and cutting.



Figures 6 – 9. Comparisons between laboratory analysis and scissor cut for Field 10 -3. This particular field and cutting was selected because it had 5 scissor cut analyses which allows for standard deviations to be calculated to determine if there are differences between method of analysis.







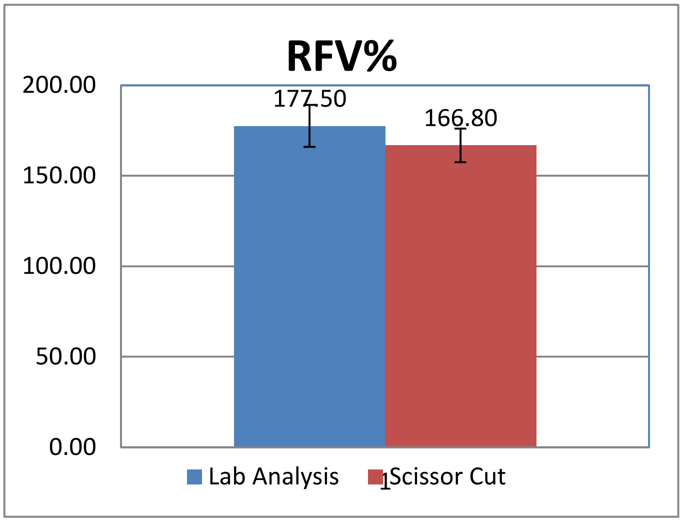


Figure 10. Relative Feed Value (RFV) for each bale of hay from one field at one cutting and the overall average for that field at that cutting (solid line). Average for all bales was 184 (SD = 14.4) and the values ranged from a maximum of 232 to a minimum of 140 (difference of 92).

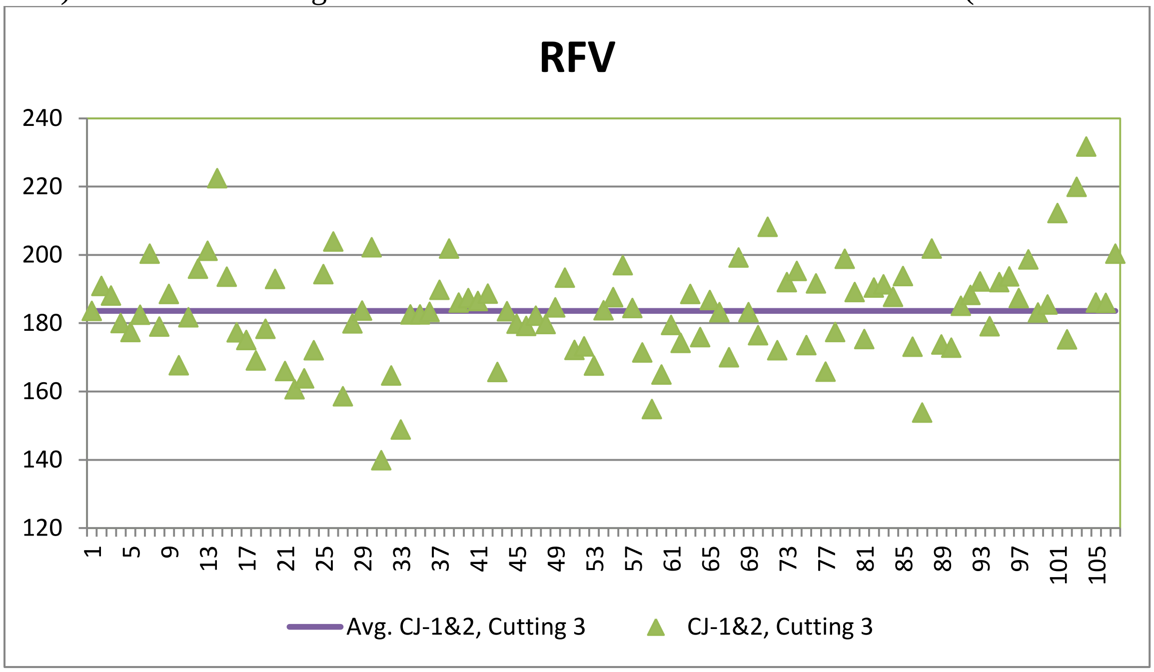


Figure 11. Laboratory moisture % compared with baler moisture % from a subset of 383 bale samples. A perfect correlation would be the line with squares.

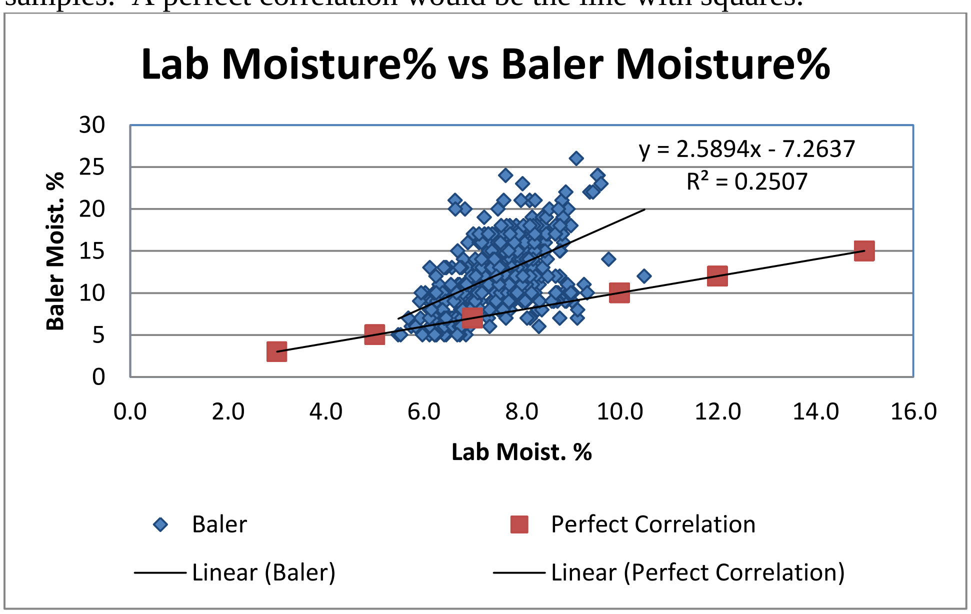


Figure 12. Correlation between bale dry matter (lb) based on laboratory analysis and bale dry matter (lb) using sensor moisture that was converted using a correction factor. The trendline used was a linear relationship.

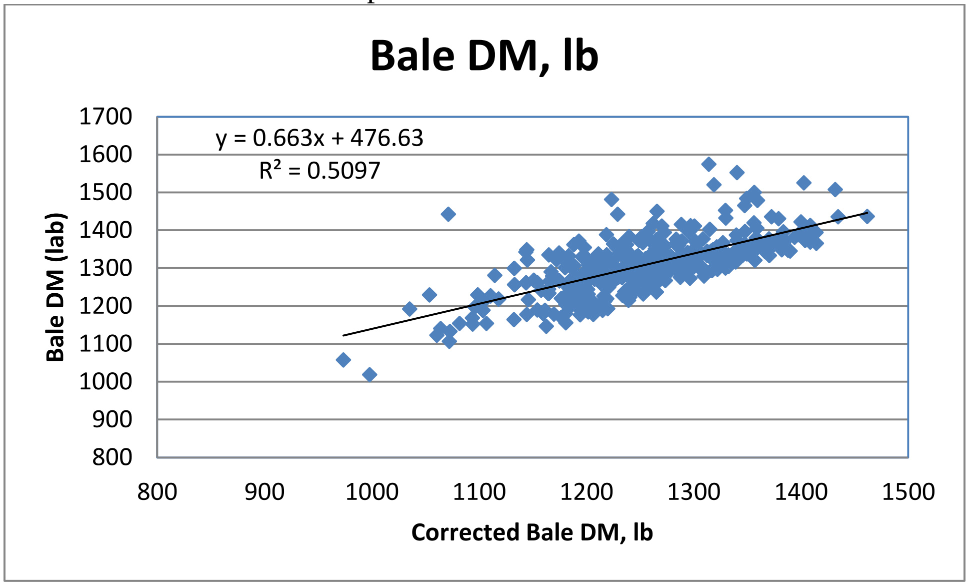


Figure 13. ADF% compared with NDF% of bale samples based on laboratory analysis.

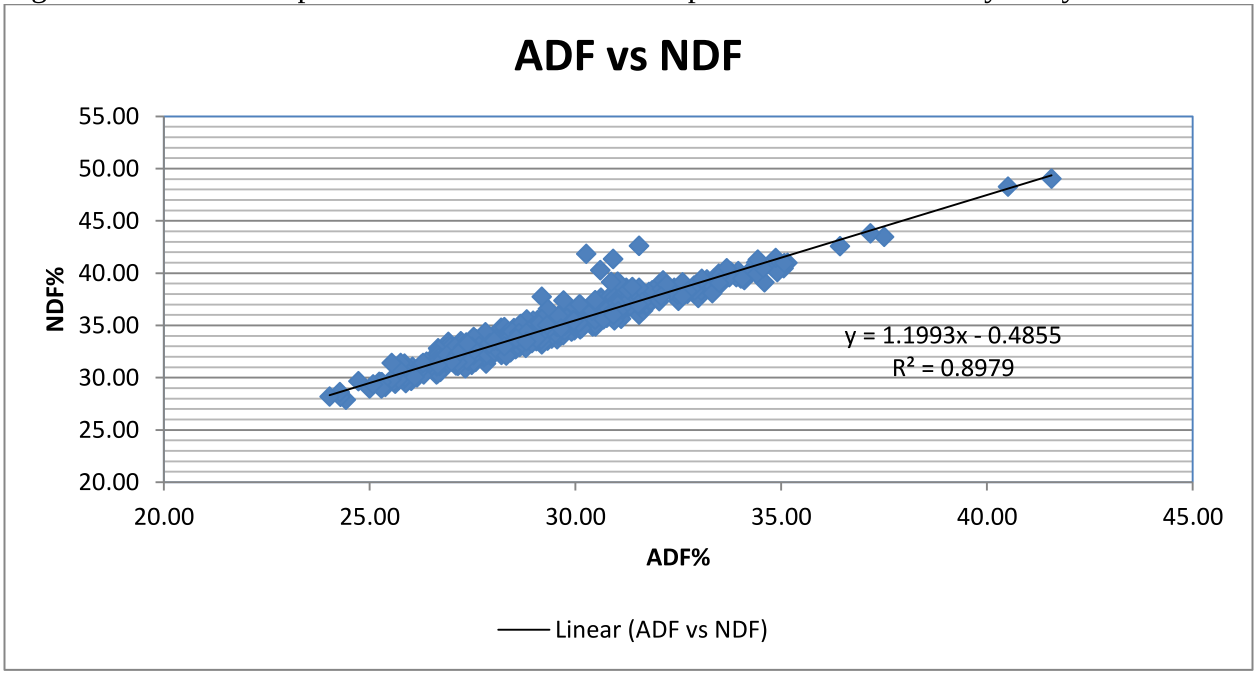


Figure 14. RFV compared with NDF%, ADF% and CP% in bale samples based on laboratory analysis.

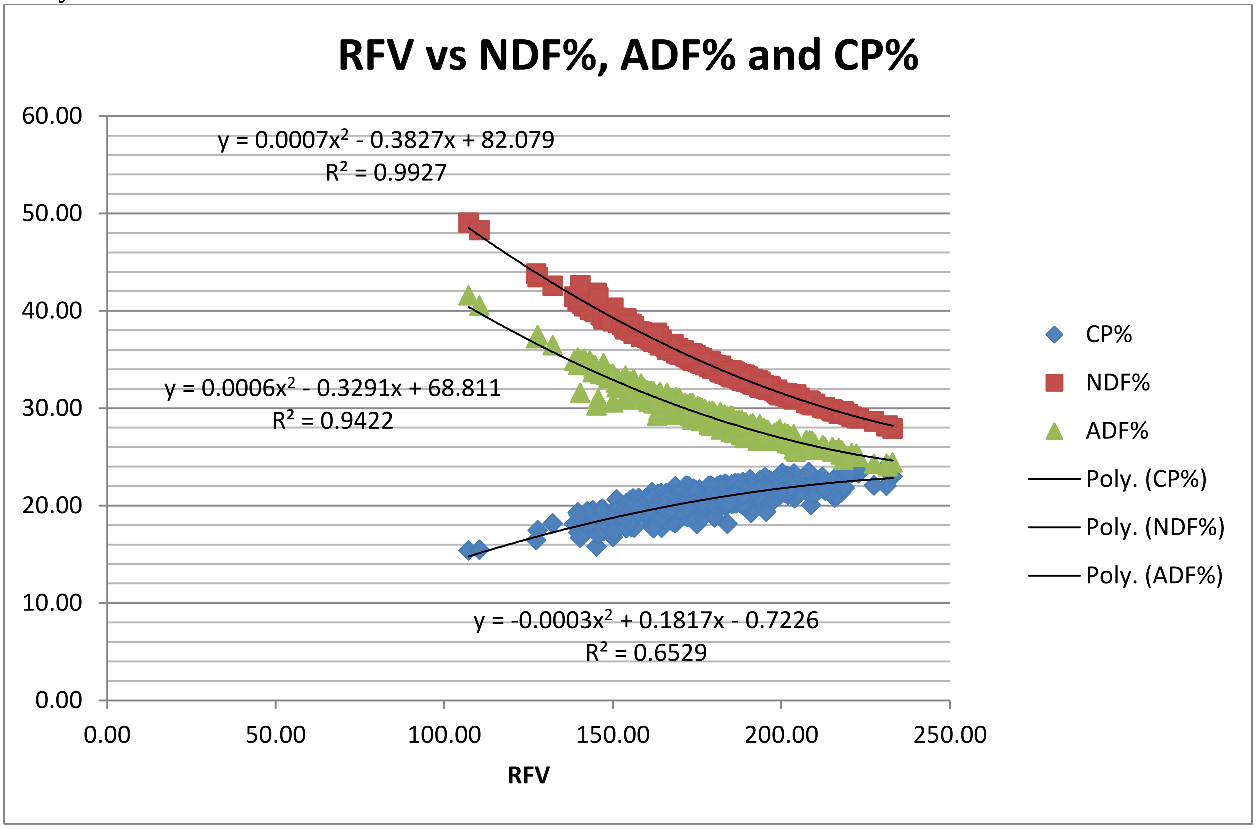


Figure 15. RFV compared with NEL in bale samples based on laboratory analysis.

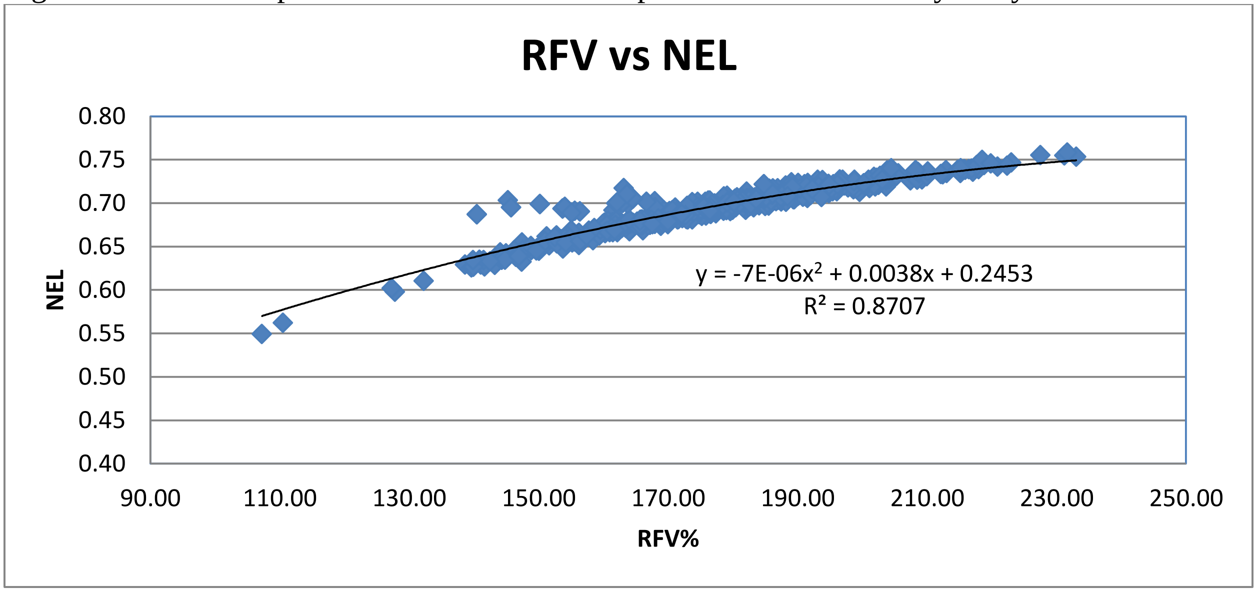


Figure 16. RFV compared with TDN% of bale samples based on laboratory analysis.

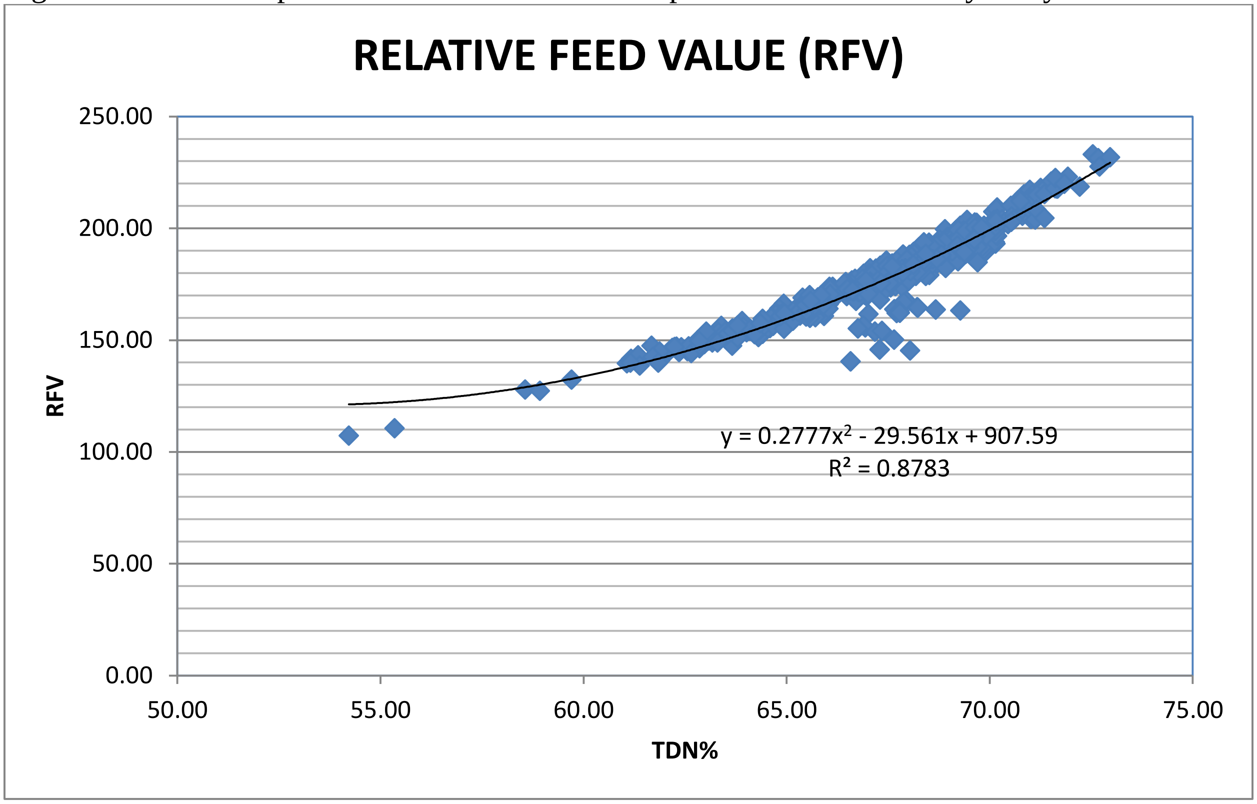


Figure 17. NDF% compared with CP%, by cutting, based on laboratory analysis.