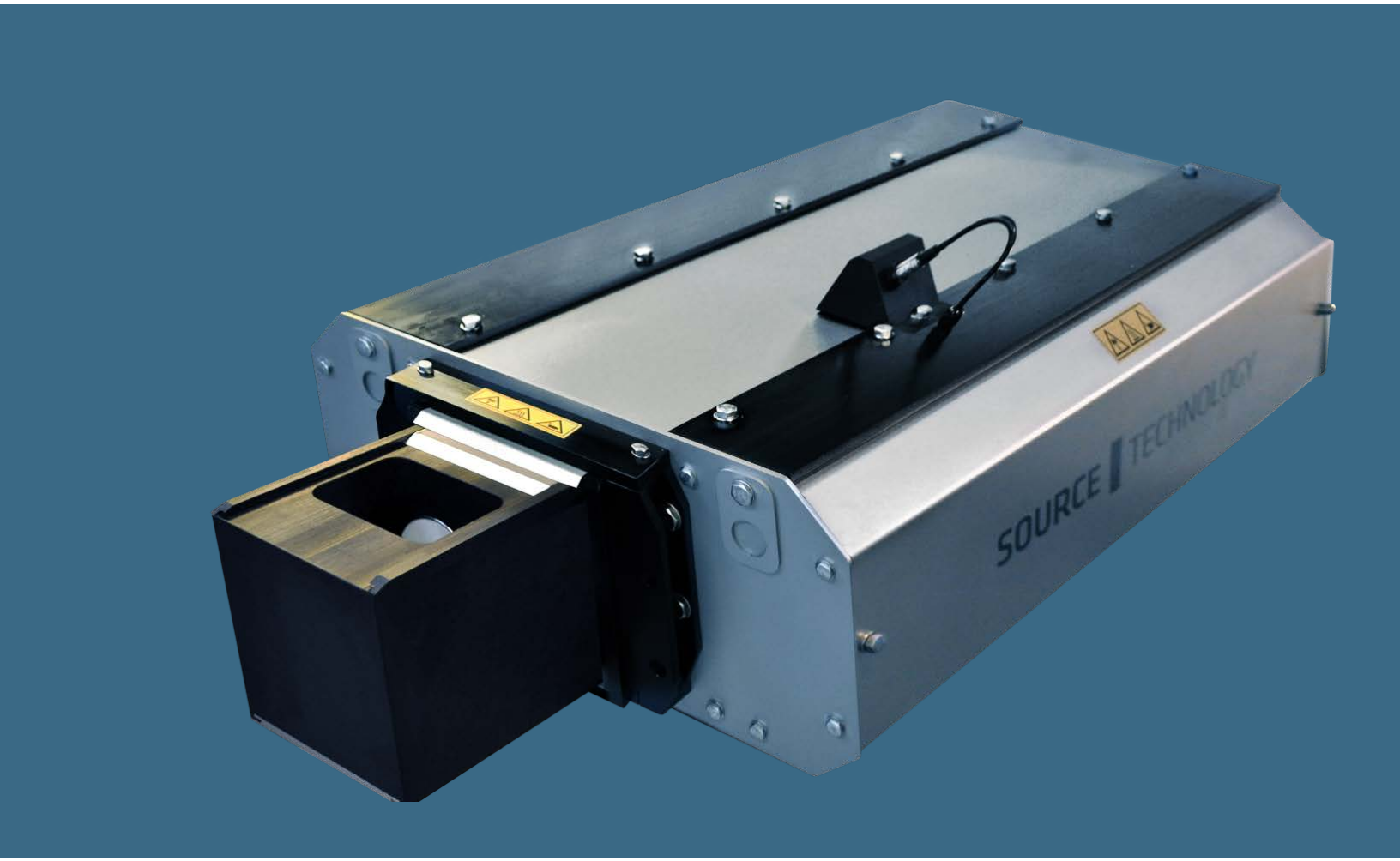
PERFORMANCE REPORT

BULK DENSITY SYSTEM

BDS™



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1. Introduction

This report describes offline and inline test results obtained by using the Source Technology automated Inline sampler model BDS™ to determine bulk density of extruded Pet Food. The BDS sampling system is an inline sampling device able to provide important product quality information to the production personnel inline such as actual bulk density. Furthermore, the sampler can interface with the plant control system in order to control essential process equipment such as an extruder or a dryer.

1.1. Functional description of Bulk Density samplers.

The BDS sampler consists of a movable sampling cup, which can be positioned in the product flow of the production line. The product sampling cup is filled and emptied with the product by opening and closing the pneumatic driven gates mounted at the top and bottom respectively. The sampling cup is attached to a weighing device (load cell), measuring the actual weight and hereby the weight of the product collected. A control system connected to the inline sampler calculates the Bulk Density using the known volume of the sample cup and the actual weight defined by the load cell signal. A bulk density result can be provided every 45 seconds.

Please click on the link below to see an animation of the working principle:
www.sourcetechnology.dk

2. Automated Inline Bulk Density measuring.

During production, the process operator has many tasks in order to ensure that the production line is running efficiently and that product quality is adequate. Therefore, controlling the bulk density might only be conducted every approx. 30 minutes, which can be a disadvantage in terms of recognizing sudden quality problems.

Another disadvantage is the human impact to on measuring bulk density manually. Each process operator has his own way of filling the sample cup used for measuring the bulk density. This factor will lead to inconsistence of the results achieved by measuring the bulk density manually as any changes of the bulk density could be related to the human factor or to the product itself.

Accuracy of measuring the bulk density manually is affected by the following facts:

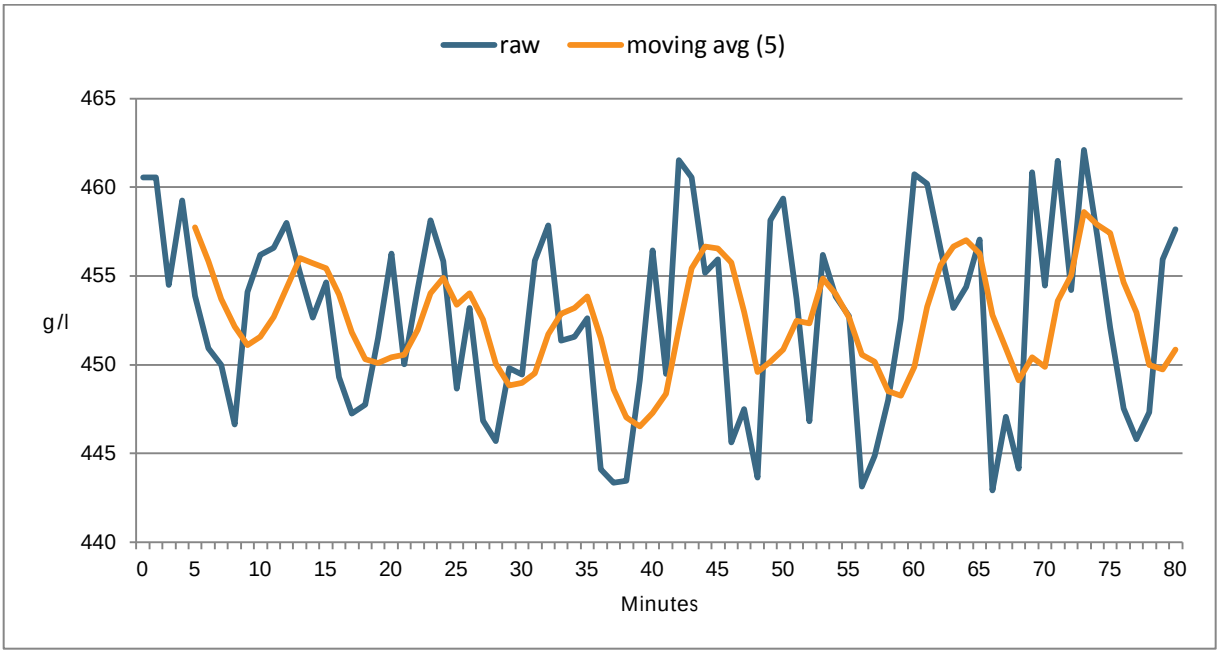
- The specific person conducting sampling.
- Procedure for sampling.
- Potentially associated equipment/tools used for sampling/measuring
- Design of the sampling cup (diameter vs. height).

A very common mistake when analyzing bulk density manually is the size of the sampling cup (please see the example below), which often turns out to be too small for the product measured. A sampling cup used for manually bulk density measuring less than 1000 ml. is not recommended.

By operating the automated inline bulk density measuring system from Source Technology, it is possible to get a bulk density measurement each approx. 45 seconds. With such a high measuring frequency it is possible to investigate the stability or instability of the Extruder or Dryer performance.

Example of an un-stable extruder (surging)

The graph below illustrates actual bulk density after the Extruder (after pneumatic pick-up). The variation in product bulk density clearly indicates that the Extruder process is unstable (surging). The blue line (raw) shows a sample with a 60 seconds interval and the red line is the moving average of five samples.

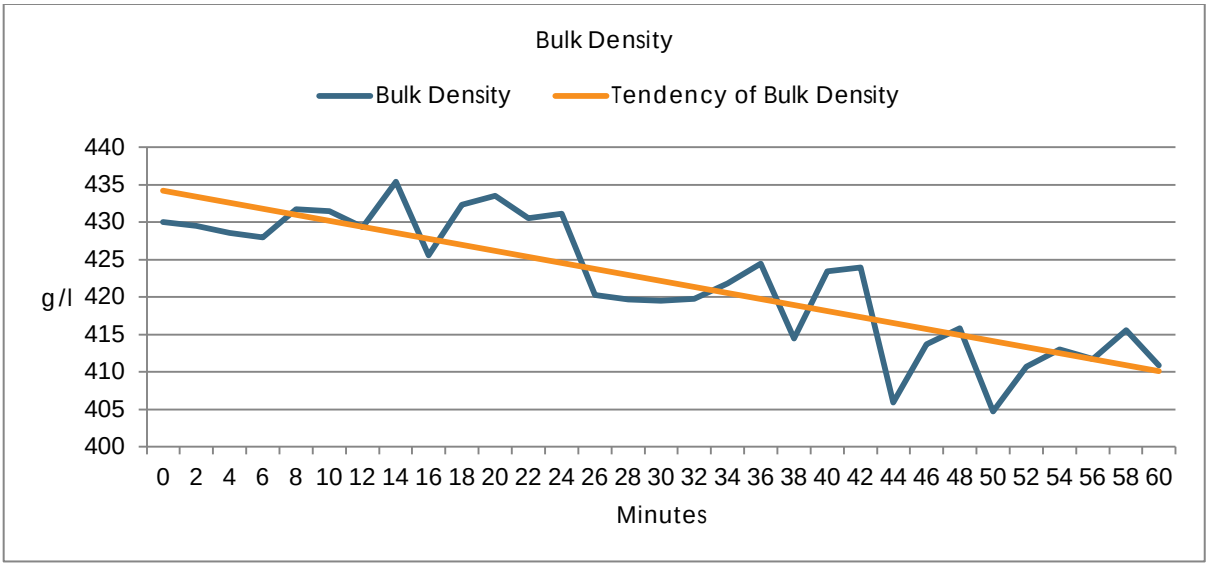


Example of an un-stable dryer (surging moisture target)

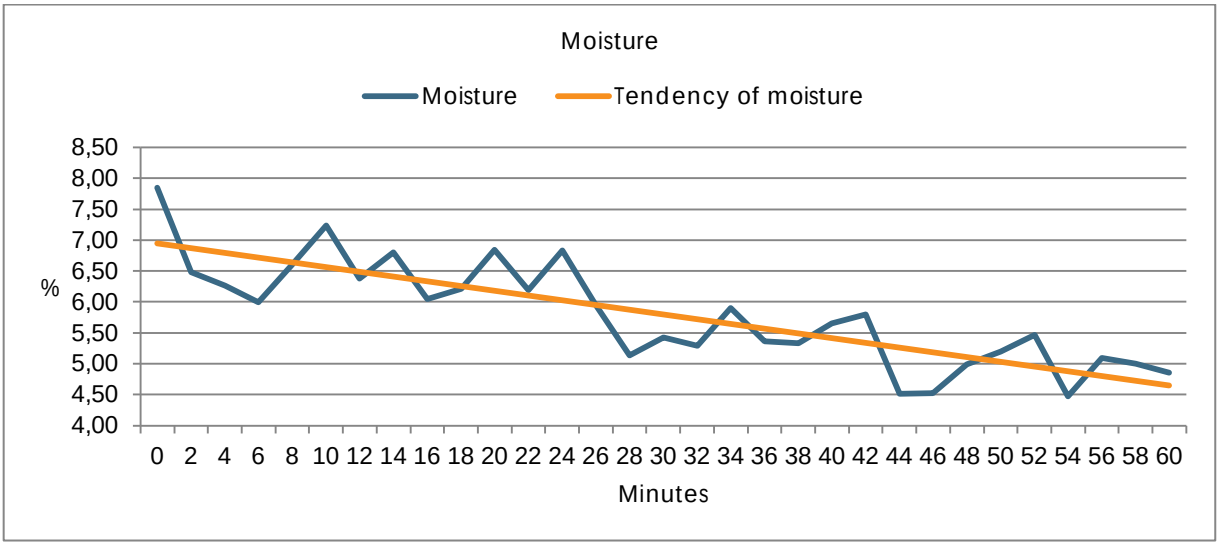
The graphs on the next page illustrates actual bulk density as well as the actual moisture after drying. Data from the inline sampler with a built-in moisture sensor installed were recorded to demonstrate the development of bulk density with surging moisture levels. The data represents one-hour production time with a sample interval of 120 seconds (two minutes).

From the graphs illustrating the development of bulk density and moisture, it can be concluded that there is an obvious correlation between the bulk density and moisture content of the product. The bulk density decrease when moisture levels decrease.

Graph illustrating inline measured bulk density at dryer outlet

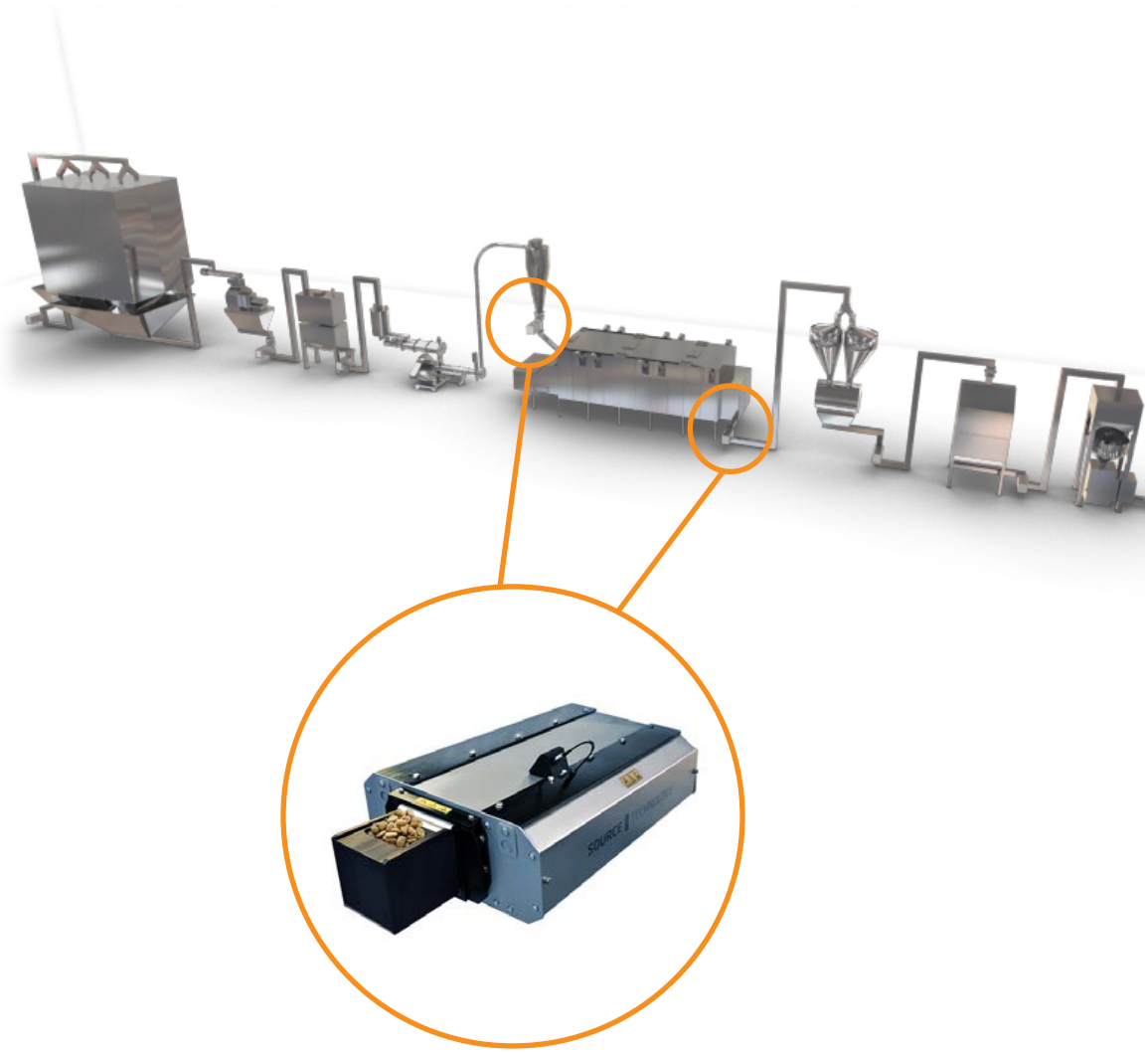


Graph illustrating inline measured moisture level at dryer outlet



3. Inline installation of the Bulk Density System

In an extrusion production line, the most common and beneficial location for the installation of the Bulk Density System, is right after the Extruder (before dryer). At this location, the Bulk density System will provide the operating personnel with important product information. The illustration below shows a BDS inline sampler installed at the outlet of the pneumatic pick-up system from the Extruder.



4. Offline Verification Test of the Bulk Density System

An offline verification test of the inline sampler model BDS was conducted. The concept of the Inline sampling is to use a conical cup with a smaller area in the top of the cup compared to the bottom. By using a minimum scraping area in the top (the smallest area) the variation in terms of uneven measuring results will be reduced to a minimum.

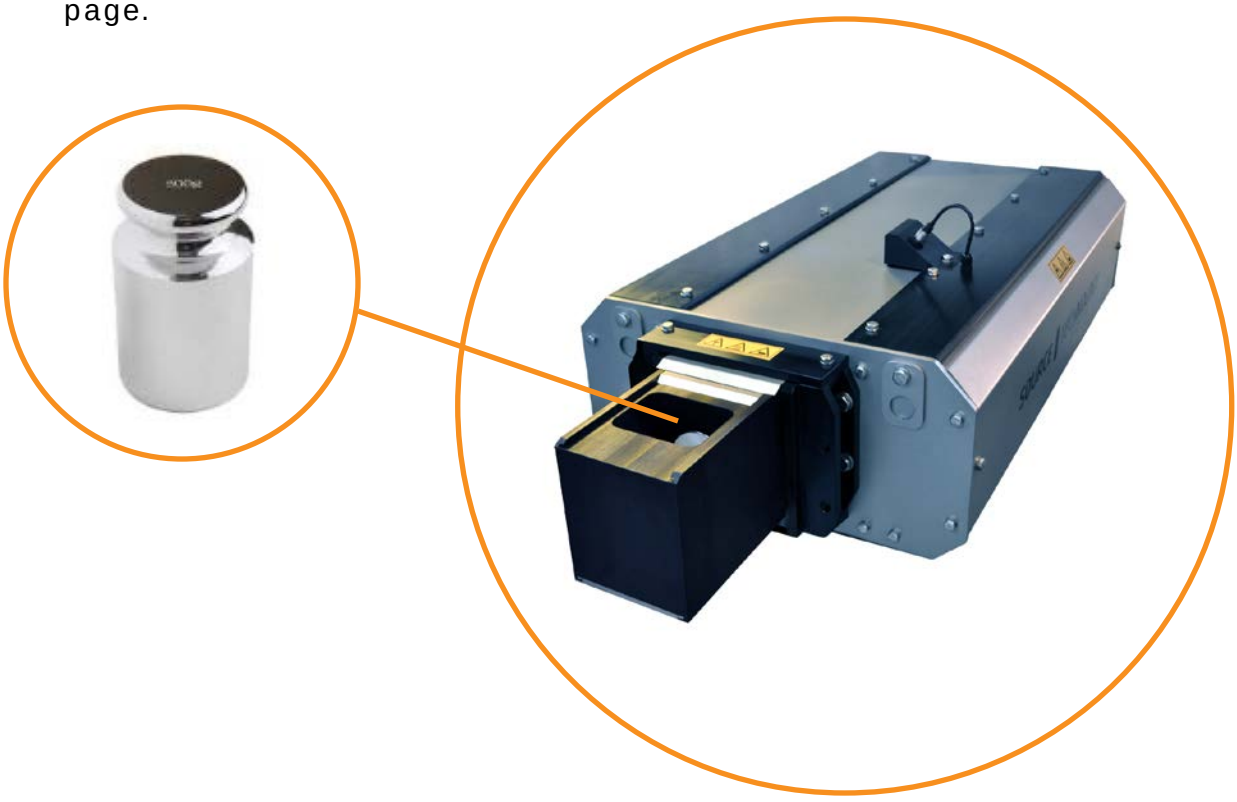
Two offline performance tests were conducted:

Test 1: Using a fixed weight (load) as a product to be filled into the sampling cup in order to document accuracy and measure repeatability of the bulk density system.

Test 2: Using cat food and dog food as a product to be filled into the sampling cup in a controlled manner in order to document accuracy and measure repeatability of the bulk density system without any interference from process equipment such as an extruder or dryer.

Test 1: Accuracy and repeatability of bulk density by using a fixed weight

Testing accuracy and repeatability of the bulk density by using a fixed weight eliminates the errors that a product can add. Thus, the weighing accuracy of the weighing system of the BDS sampler can be defined.
A fixed weight of 400 gram was dropped into the cup while the cup was in a sampling position. The bulk density value calculated by the control system was reported. This procedure was performed five times. Please find the results on the next page.



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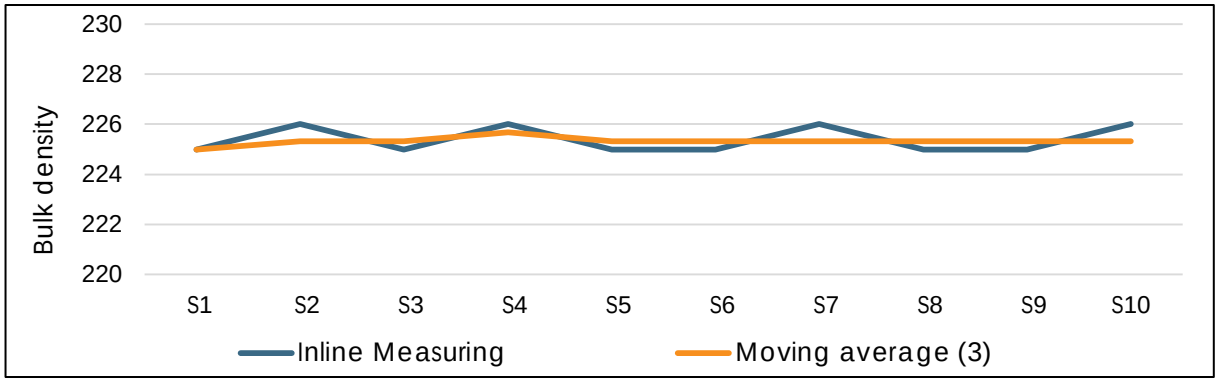
Test result from the offline weighing test of the Bulk Density System

Product type	Load (400 gram)	
Product shape		
Product size	N/A	
Sampling cup size	1.850 ml.	5.000 ml.
Sampling reference	**Inline Sampler** g/l	**Laboratory** g/l
Sample no.:	Measurement	Measurement
S1	225	
S2	226	
S3	225	
S4	226	
S5	225	
S6	225	
S7	226	
S8	225	
S9	225	
S10	226	
Min. measured value (g/l)	225	
Max. measured value (g/l)	226	
Difference (g/l)	1	
Average measurement (g/l)	225	
Accuracy (g/l)	**0,5**	
Standard deviation	**0,49**	

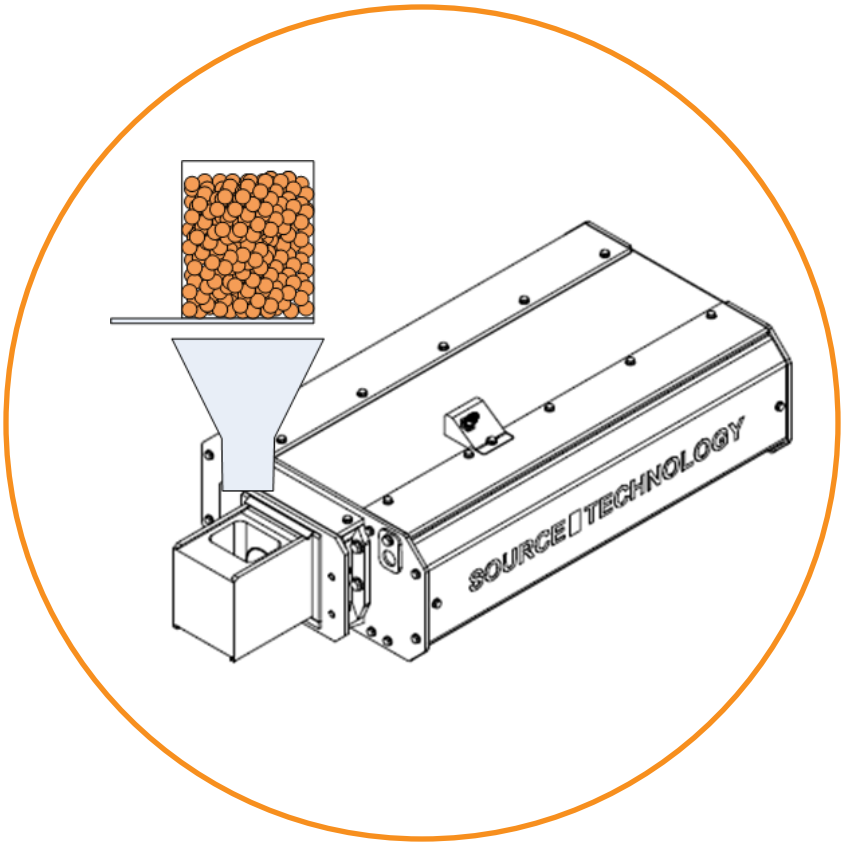


Test 2: Offline measuring repeatability by using dry pet food

A test was performed to analyze the measuring repeatability of the bulk density, by using a small-sized and a large-sized product respectively. To minimize the errors that might occur during the cup filling by hand, a special filling device were used to overfill the cup during this test.

The test product used was extruded dry pet food as these products are typically the most difficult ones to measure in terms of accuracy. On other products such as extruded aquatic feed one will on similar product sizes find the accuracy superior to the results listed.

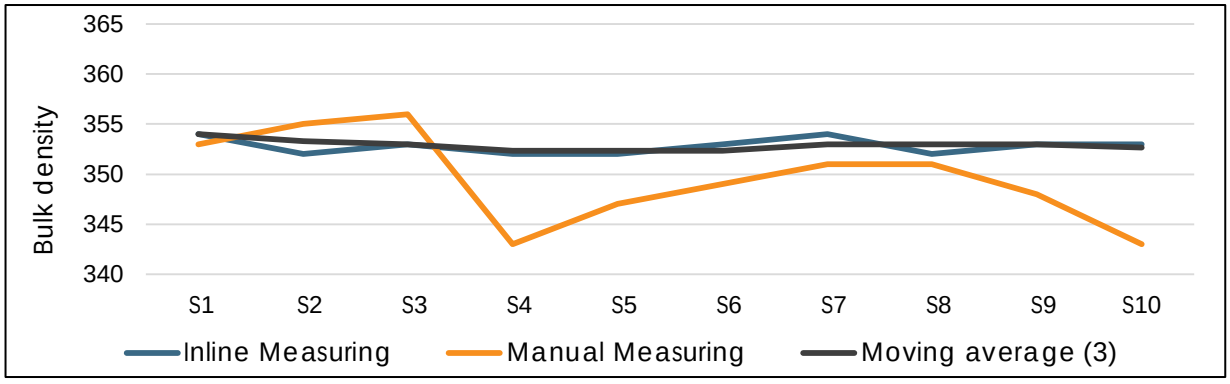
The filling device consists of a cup with a slide in the bottom, which can be opened to let the material out. The material flows through a slightly tapered funnel to ensure that the material flows equally into the cup of the bulk density unit.



When an overfill of the sampling cup is present the bulk density system analyze the sample in the exact same manner as an inline installation. The bulk density result is calculated by the control system and reported. This procedure is repeated 10 times for each product. The result appears from the next pages.

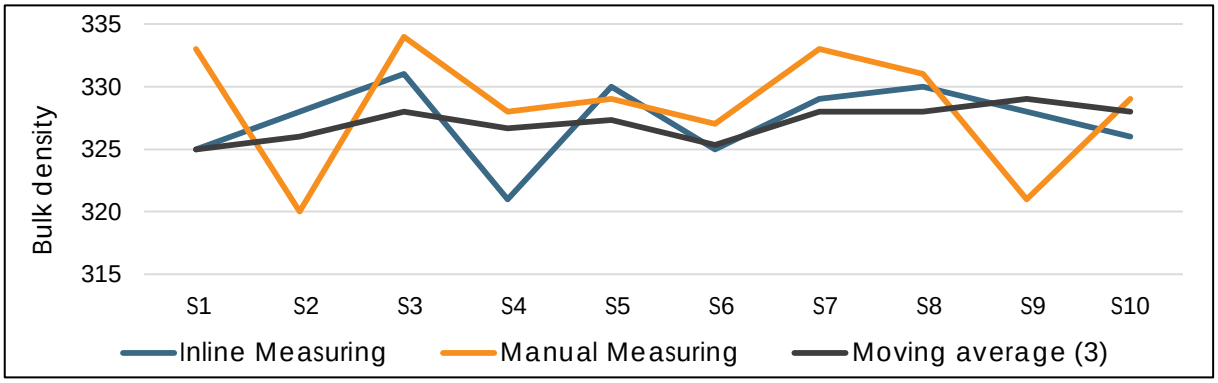
Test result - Offline measuring repeatability – Dry Cat Food

Product type	Cat Food	
Product shape		
Product size	8x8 mm	
Sampling cup size	1.850 ml.	5.000 ml.
Sampling reference	**Inline Sampler** g/l	**Laboratory** g/l
Sample no.:	Measurement	Measurement
S1	354	353
S2	352	355
S3	353	356
S4	352	343
S5	352	347
S6	353	349
S7	354	351
S8	352	351
S9	353	348
S10	353	343
Min. measured value (g/l)	352	343
Max. measured value (g/l)	354	355
Difference (g/l)	2	12
Average measurement (g/l)	353	350
Accuracy (g/l)	**1**	**6**
Standard deviation	**0,75**	**4,27**



Test result - Offline measuring repeatability – Dry Dog Food

Product type	Dog Food	
Product shape		
Product size	20x10 mm	
Sampling cup size	1.850 ml.	5.000 ml.
Sampling reference	**Inline Sampler** g/l	**Laboratory** g/l
Sample no.:	Measurement	Measurement
S1	325	333
S2	328	320
S3	331	334
S4	321	328
S5	330	329
S6	325	327
S7	329	333
S8	330	331
S9	328	321
S10	326	329
Min. measured value (g/l)	321	321
Max. measured value (g/l)	331	333
Difference (g/l)	10	12
Average measurement (g/l)	327	329
Accuracy (g/l)	**5**	**6**
Standard deviation	**2,90**	**4,57**



5. Inline Verification Test of the Bulk Density System

In order to document the measuring accuracy and repeatability of the inline sampler model BDS two systems were installed in an extruded pet food process line. One sampler was installed after the extruder (before the dryer) and the other one after the dryer. Thus, the performance of wet as well as dry pet food could be documented.

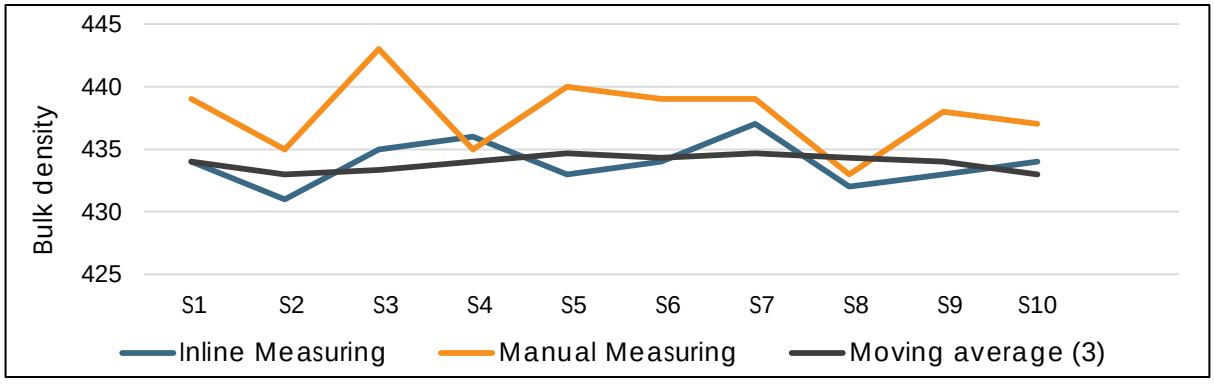
The conclusion of the tests was as follow:

Product	**Cat Food Wet**	**Cat Food Dry**	**Dog Food Wet**	**Dog Food Dry**
Size	7x9 mm	7x9 mm	20x10 mm	20x10 mm
No. of samples	10 pcs.	10 pcs.	10 pcs.	10 pcs.
Average density	467 g/l	434 g/l	388 g/l	366 g/l
Accuracy	±4.0 g/l	±3.0 g/l	±5.5 g/l	±4.5 g/l
Standard deviation	2.33	2.75	3.17	3.55

NOTE. Please find the detailed results on the next pages!

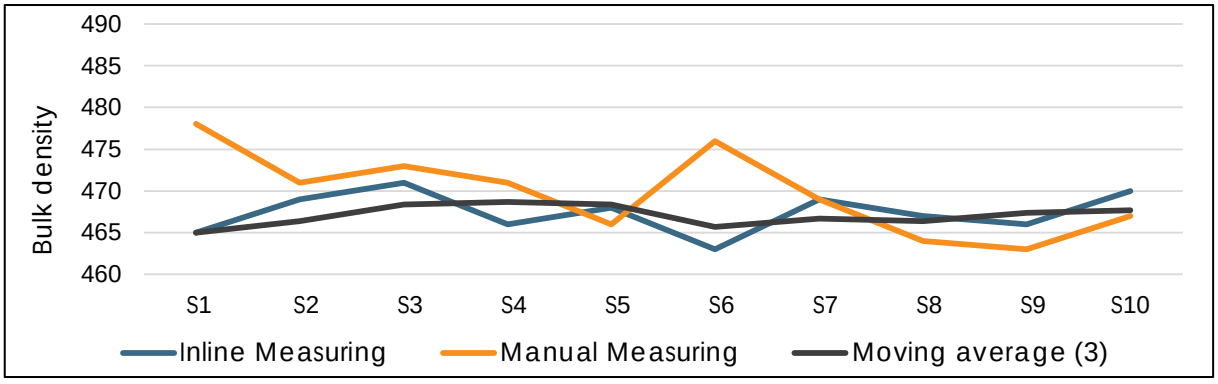
Test result - Inline measuring repeatability – Dry Cat Food

Product type	Cat Food	
Product shape		
Product size	7 x 9 mm	
Sampling cup size	1.850 ml.	5.000 ml.
Sampling reference	**Inline Sampler** g/l	**Laboratory** g/l
Sample no.:	Measurement	Measurement
S1	434	439
S2	431	435
S3	435	443
S4	436	435
S5	433	440
S6	434	439
S7	437	439
S8	432	433
S9	433	438
S10	434	437
Min. measured value (g/l)	431	435
Max. measured value (g/l)	437	443
Difference (g/l)	6	8
Average measurement (g/l)	434	438
Accuracy (g/l)	**3**	**4**
Standard deviation	**1,70**	**2,75**



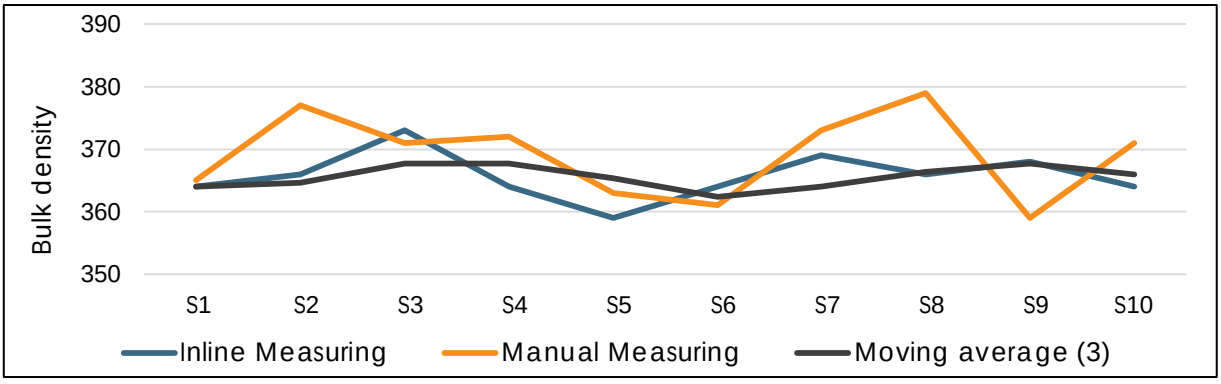
Test result - Inline measuring repeatability – Wet Cat Food

Product type	Cat Food	
Product shape		
Product size	7 x 9 mm	
Sampling cup size	1.850 ml.	5.000 ml.
Sampling reference	**Inline Sampler** g/l	**Laboratory** g/l
Sample no.:	Measurement	Measurement
S1	465	478
S2	469	471
S3	471	473
S4	466	471
S5	468	466
S6	463	476
S7	469	469
S8	467	464
S9	466	463
S10	470	467
Min. measured value (g/l)	463	463
Max. measured value (g/l)	471	478
Difference (g/l)	8	15
Average measurement (g/l)	467	470
Accuracy (g/l)	**4**	**7,5**
Standard deviation	**2,33**	**4,71**



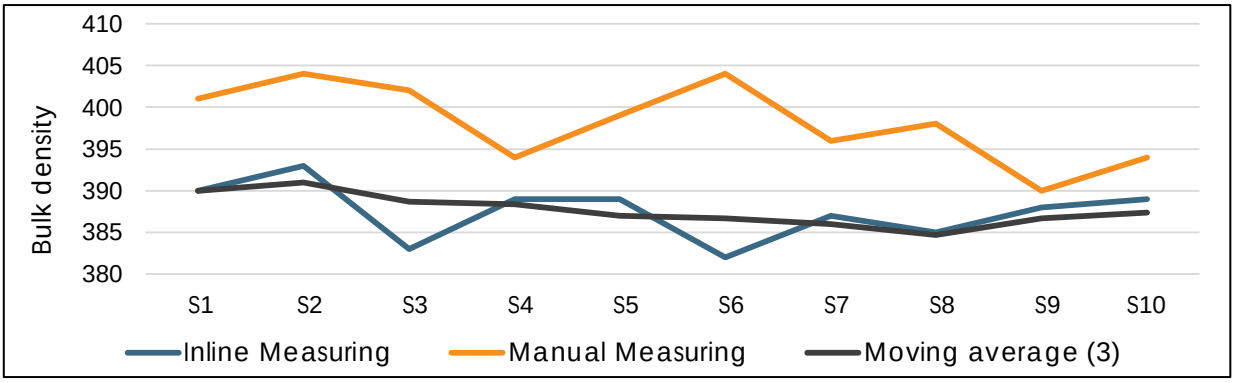
Test result - Inline measuring repeatability – Dry Dog Food

Product type	Dog Food	
Product shape		
Product size	20x10 mm	
Sampling cup size	1.850 ml.	5.000 ml.
Sampling reference	**Inline Sampler** g/l	**Laboratory** g/l
Sample no.:	Measurement	Measurement
S1	364	365
S2	366	377
S3	373	371
S4	364	372
S5	359	363
S6	364	361
S7	369	373
S8	366	379
S9	368	359
S10	364	371
Min. measured value (g/l)	364	359
Max. measured value (g/l)	373	371
Difference (g/l)	9	12
Average measurement (g/l)	366	369
Accuracy (g/l)	**4,5**	**6**
Standard deviation	**3,55**	**6,43**



Test result - Inline measuring repeatability – Wet Dog Food

Product type	Dog Food	
Product shape		
Product size	20x10 mm	
Sampling cup size	1.850 ml.	5.000 ml.
Sampling reference	**Inline Sampler** g/l	**Laboratory** g/l
Sample no.:	Measurement	Measurement
S1	390	401
S2	393	404
S3	383	402
S4	389	394
S5	389	399
S6	382	404
S7	387	396
S8	385	398
S9	388	390
S10	389	394
Min. measured value (g/l)	382	390
Max. measured value (g/l)	393	404
Difference (g/l)	11	14
Average measurement (g/l)	388	398
Accuracy (g/l)	**5,5**	**7**
Standard deviation	**3,17**	**4,45**



6. Bulk Density – Conclusion

It can be concluded that the Source Technology inline bulk density system model BDS can provide accurate bulk density measurements. Both offline and inline tests documented that the accuracy of the inline sampler model BDS is superior to manually measuring (by using a high volume sampling cup of 5.000 ml). Furthermore, it can be concluded that the accuracy of the inline bulk density system is sufficient to use for measurements in an overall control system in order to control essential process equipment such as the extruder. Using the inline bulk density results to automatically adjust SME (Specific Mechanical Energy) or STE (Specific Thermal Energy) will ensure a superior performance of the extruder.

Under stable operating conditions the extruder and dryer the following measuring accuracies of the inline sampler model BDS™ can be guaranteed:

Product	Accuracy <10 mm diameter	Accuracy >10 mm diameter
Wet Aquatic Feed	1-6 g/l	1-9 g/l
Dry Aquatic Feed	1-6 g/l	1-9 g/l
Wet Pet Food	1-6 g/l	1-9 g/l
Dry Pet Food	1-6 g/l	1-9 g/l