Assessment of Temperature Changes During the Shipping of Male Latex Condoms and the Impact of these Changes on the Properties of the Condoms

May 2021

© UNFPA Kenya/ Luis Tato

UNFPA

Ensuring rights and choices for all since 1969

Table of Contents

Acknowledgements

The 'Assessment of Temperature Changes During the Shipping of Male Latex Condoms and the Impact of these Changes on the Properties of the Condoms' was performed by United Nations Population Fund (UNFPA) to improve on quality of Reproductive Health (RH) commodities supplied and to ensure Purchaser-user protection. UNFPA appreciates the expertise of the main author of the study, Dr. William Potter. Co- authors of this study are Ms. Seloi Mogatle (UNFPA) and Ms. Linda Serwaa (UNFPA).

Chapter 1: Introduction

This report compares the results of two shipping studies on male latex condoms conducted by UNFPA in which the temperatures of the consignments were monitored during transit between the manufacturers and destination countries. The condoms were also tested before and after shipment. In the first study the condom manufacturer was based in Thailand and the condoms were shipped to Uganda between December 2017 and February 2018. In the second study the manufacturer was based in India and the condoms were shipped to Nigeria between September 2018 and February2018.

Chapter 2: Background

As part of its mandate, UNFPA is guided by the Quality Assurance Framework for the procurement of RH commodities, which describes the quality assurance processes before, during, and after procurement, and recognizes that the different steps in the supply chain are inter-connected in relation to assuring delivery of a quality product to the public. One potential risk to the quality of RH commodities is exposure to extreme temperature conditions during shipping and customs clearance, particularly when products are being shipped between manufacturers and destination sites in countries with hot climates. Therefore, the Procurement Services Branch (PSB) Quality Assurance Office has introduced a temperature monitoring programme for RH commodities under procurement, in an effort to improve the quality of RH commodities that are available to the end user, thereby safeguarding the health of the public.

Chapter 3: Methodology

During shipping and while awaiting customs clearance temperatures within the containers are monitored using data loggers. The loggers are placed in different locations within the containers (top, middle and bottom) and within the pallets (top, middle and bottom). After shipping the temperature results are analysed to determine the mean temperatures, mean kinetic temperatures (MKT) and maximum and minimum temperatures over the shipping period. The MKT takes in to account the exponential nature of the changes in chemical reaction rates with respect to temperature that can lead to changes in properties of the products. Theoretically, as long as the MKT remains at or below 30 °C, the shelf life of the products, which will have been established at a temperature of 30 °C, should be unaffected by any temperature excursions that might occur during shipping.

The impact of temperature excursions on the properties of some products, and particularly condoms, can be difficult to assess without conducting further tests. The calculation of MKTs assumes that the effects of temperature changes on the stability of the products can be described by the Arrhenius Equation. This relies on certain assumptions about a key parameter in that equation, the value of the activation energy. The first assumption is that the activation energy remains constant over the temperature range to which the condoms are exposed. The second is the value of the activation energy. Most calculations of MKT are based on the assumption that the activation energy is 83.14472 kJ/mol. This activation energy is close to the middle of the range for many chemical reactions but using this value also simplifies the calculation of MKT since it is a simple multiple of the value of R, the gas constant, which also appears in the condom.

The assumption that the activation energies for changes in burst pressure and volume are independent of temperature is generally not true. Simulation studies have shown, however, that the difference between mean temperature and MKT is relatively insensitive to the value of activation energy used in the calculation. For example, in a simulation based on real shipping data, a combination of a peak temperature of 48.0 °C, a minimum temperature of 17.4 °C and an overall average of 29.7 °C, the MKT increased from 32.1 °C to 35.0 °C when the activation energy used in the calculation was doubled (i.e. increased from 83.14 kJ/mol to 166.29 kJ/mol kJ/mol). The relative insensitivity of MKT to the value of the activation energy used in the calculation suggests therefore that it should have utility as a parameter for assessing if condom shipments have been exposed to excessively high temperature excursions that might affect the shelf life of the condoms. Nevertheless, given that the activation energies for changes in burst properties are not necessarily constant with changes in temperature, periodic monitoring of condom properties after shipping is required to confirm the usefulness of MKT as an indictor of acceptable shipping conditions.

Details of the two shipping studies that are the subject if this report are included in Table 1.

3.1: Table 1: Summary Details of the Studies:

Study ID	Condom Source	Destination	Number of Consignments	Number of Condom Lots Tested	Shipping Period	Transit Duration (Days)
Uganda	Thailand	Uganda	1	19	25 Dec 17 to 18Feb 18	55
Nigeria	India	Nigeria	1	10	26 Sept 17 to 12 Oct 18	16
			2		28 Dec 18 to 26 Feb 19	60

Prior to shipping to the original destination county, all condom lots were subject to pre-shipment testing in accordance with UNDPA's standard practice. Each lot was assessed against the full set of quality requirements specified in ISO 4074:2015 and the WHO/UNFPA Specification for Male Latex Condoms. Testing was conducted at UNFPA approved laboratories accredited to ISO 17025 for testing male condoms.

Samples from condom lots post shipment were taken from in-country stocks by UNFPA approved sampling organisations and sent to the selected ISO 17025 accredited laboratory for testing. Post shipment tests were restricted to the key performance requirements of burst properties, freedom from holes and visible defects, and package integrity. Sample sizes for post shipment testing were based on the original lot sizes to ensure the tests retained adequate power to assess conformance with ISO 4074 requirements.

In the Ugandan shipping study, condoms taken from retained sample stocks were used as comparators for the samples of shipped condoms returned from the country. The retained samples had been kept under controlled storage conditions as specified in the WHO/UNFPA Specification. By using retained samples as the comparator, any impact of time related changes in condom properties due to storage should have been minimised. Both the retained and post shipment sample were tested at the same laboratory to minimise the impact of between laboratory variability.

In the Nigerian study the results for per-shipment testing were compared directly with the post-shipment results. Again, both pre and post shipment tests were done at the same laboratory.

The time interval between pre and post shipment testing was about 13 months. This means that some time related changes in properties could have occurred between the two sets of tests which may impact the interpretation of the results.

In addition to the tests reported above, tensile tests were also carried out on the Ugandan samples. Since tensile testing was not conducted on the Nigerian samples a comparative assessment of the impact of shipping on condom tensile properties across the two studies cannot be made.

3.2: Mean Kinetic Temperatures and Temperature Excursions

The MKTs recorded over the shipping periods for the Ugandan condoms varied between 27.9 °C to 30.3 °C. Approximately half of the lots were exposed to temperature excursion significantly higher than 35 °C (range 38.6 °C to 43.8 °C) and the remainder to minor temperature excursion in the range 31.5 °C to 33.5 °C. Despite experiencing temperature excursions above 35 °C, the MKTs generally remained under 30 °C except for one lot (17PN980) which reached 30.3 °C, i.e. slightly over 30 °C. Such a small rise in MKT above 30.0 °C is highly unlikely to have any significant impact on the shelf lives of the condoms. Table 1 summarises the data logger outputs recorded during the Ugandan shipments (Note: mean temperatures recorded during each shipment are not avaible).

The mean kinetic temperatures recorded in the Nigerian shipments ranged from 28.3 °C to 32.0 °C. The highest peak temperature recorded was 48.0 °C. The MKT recorded by the data logger that captured this temperature was 31.8 °C. The lack of significant impact of the high temperature excursion on the MKT can be explained by the relatively short duration over which these peak temperatures occurred coupled with the minimum temperatures dropping to as low as 14.7 °C. Table 2 summarises the data logger outputs recorded during the Nigerian shipments

The highest MKTs recorded in the Nigerian shipment were from data loggers located at the top of the containers, which is to be expected since hot air within the containers would rise to the top. The MKTs were also only 0.3 °C to 1.4 °C higher than the average temperatures recorded over the shipping period. This is consistent with results from other shipping studies on condom consignments. Typically, mean MKTs exceed the average recorded temperatures by just 1 °C to 2 °C.

3.3: Condom Test Results

In both studies the results for freedom from holes, visible defects and package integrity were excellent even after shipping. Only one lot (17PN904) was found to have any nonconforming condoms with respect to freedom from holes when the samples shipped to Uganda were tested. This lot still conformed to the requirements of ISO 4074:2015 (2 nonconforming condoms were found in the test sample of 500 tested which is lower that the acceptance number of 3).

In the case of the shipments to Nigeria, no nonconforming condoms with respect to visible defects and package integrity either before or after shipping. In pre-shipment testing no nonconforming condoms with respect to freedom from holes were found in any of the lots (in total 3,150 condoms were tested). One nonconforming condom was found in each of four lots out of the 10 lots tested post shipment. The overall rate of nonconforming condoms post shipment was therefore 4/5,000 or 0.08%. The differences in nonconformity rates between individual lots before and after shipment were not statistically significant when assessed by Fisher Exact test ($p < 0.05$). The same is true for the pooled results taken across all of the lots. In total there were no nonconforming condoms in the total sample of 3,150 tested before shipment and 4 nonconforming condoms in the sample of 5,000 tested after shipping. This difference is not statistically significant (2-sided p = 0.164 by Fisher Exact test).

It can be concluded therefore that shipping did not have any statistically significant impact on the quality of the condoms with respect to freedom from holes, visible defects and package integrity in either of the studies.

In the Ugandan study, all lots conformed to the requirements of ISO 4074:2015 with respect to burst properties irrespective of whether they were the factory retained samples or the samples shipped to Uganda. The overall rate of nonconforming condoms in the samples that had been shipped to Uganda was marginally lower than the equivalent rate for the retained samples (0.40% compared to 0.55%) but this difference is not statistically significant (two-tailed p = 0.35 by chi squared test with Yates correction). The rates of nonconforming condoms for the lots exposed to temperature excursion above 35 °C during shipping were virtually identical to those that had remained below 35 °C (0.41% compared to 0.39%). This very small difference is not statistically significant (p = 0.88).

Similarly, in the Nigerian study all condom lots conformed to the requirements of ISO 4074:2015 for burst properties both before and after shipping between India and Nigeria. In pre-shipment testing four lots were found to have a single nonconforming condom in each sample of 315 tested. Post shipment to Nigeria, 9 out of the 10 lots were found to have one or more nonconforming condoms. In total there were 17 nonconforming condoms out of the 3,150 tested. Considering each lot in isolation, the difference between the pre and post shipment rates of nonconforming condoms with respect to burst properties are not statistically significant but if the total numbers of pre and post shipment nonconforming condoms across all of the lots are compared then statistical significant is achieved (2-sided p = 0.007 by Fishers Exact test).

It can be concluded therefore from both studies that temperature excursion which result in the MKTs remaining at or below 30 °C have no effect on the conformance of the condoms with respect to the burst property requirements specified in ISO 3073:2015. This also appears to be true when the MKT during shipping marginally exceeds 30 °C (up to 31.9 °C in the case of lot 1811953622 which was shipped between India and Nigeria).

A review of changes in average burst pressures and volumes can provide a more sensitive assessment of the impact of shipping on the properties of the condoms. These changes may be too small to impact significantly the probability of lots being accepted or rejected but they can detect when changes in the properties of the condoms have occurred.

The differences in average burst volumes per lot between the retained samples and those shipped to Uganda varied considerably, ranging from a reduction in volume of 14.1% to an increase of 18.6%. These changes are illustrated graphically in Chart 1 for burst volumes and Chart 2 for burst pressures (see Annex). The 95% confidence intervals for the ratios of relative burst properties for each lot after shipping divided by the property before shipping expressed as percentages are plotted for each lot. If the confidence intervals straddle the 100% line then there has been no statistically significant change on burst properties due to shipping. If the 95% confidence intervals fall completely below the 100% line then there has been a statistically significant decrease in that property. If the 95% confidence intervals fall completely above the 100% line, then there has been a statistically significant increase in that property.

The majority of these differences were statistically significant as can be seen in the charts and confirmed by the t-test. It is important to note that statistically significant differences included both increases and decreases in average bust volumes. Since all of the condoms conformed to the requirements of ISO 4074:2015, the overall differences in stability are not considered to be important. With one exception, all of the lots shipped to Uganda had average burst volumes above 30 litres (lot 17PN980 had an average burst volume of 29.3 litres). Taken across all of the lots, the average difference in burst volume between the lots shipped to Uganda and the retained samples was an increase of 0.3%.

There was much less variation in average burst pressures per lot between the retained samples and those shipped to Uganda. The difference ranged from a reduction of 6.2% to an increase of 3.7%. Many of the differences were statistically significant but of no practical importance. Both statistically significant increases and decreases in burst pressure were seen.

Charts 3 and 4 show the equivalent ratios of burst properties after shipping for the Nigerian Study. Average burst volumes and pressures after shipping were lower for all lots when compared with the pre-shipment results. Reductions in burst volume ranged between 5.4% and 17.4% per lot and burst pressures between 8.1% and 32.0%. In all cases the reductions were highly statistically significant when assessed by the t-test ($p \ll 0.001$).

The changes in burst properties before and after shipping observed in the Nigerian study can be explained in part by the very high pre-shipment results. The overall average burst volume was 46.5 litres and burst pressure 2.35 kPa. Post-shipment testing was carried out an average 13 months after the pre-shipment tests when the overall average burst volume and pressures had dropped to 40.9 litres and 1.92 kPa respectively. These are still very respectable averages and the risk of individual lots failing when tested remains very low. The long time period between the pre-shipment and post shipment testing will almost certainly have also contributed to the observed differences in burst properties.

3.4: Comparative Stability of Two Condom Types used in the study

Condoms from two different manufacturers were used in these studies. The condoms in the Ugandan study were manufactured in Thailand. Those in the Nigerian study were manufactured in India. Based on a review of stability studies on the two different condom types, the condoms manufactured in Thailand exhibited more stable burst properties over time in both real time and accelerated stability studies compared to those manufactured in India. Coupled with the use of retained samples as the comparator condoms, which ensured that the pre-shipment and post-shipment samples were of similar age at the time of testing, this would lead to an expectation that the two sets of results would be very similar unless the shipped condoms had been exposed to significantly different MKTs during shipping. Overall, therefore, the results of the Ugandan shipping trial are entirely consistent with expectations.

The stability study results for the Nigerian condoms showed that over a storage period of one year at a mean temperature of 30 °C no significant drop in burst volume and a drop in burst pressure of about 8% might be expected. In the shipping study the reductions in both burst volume and pressure, as reported above, were significantly higher than this despite the MKTs remaining broadly at 30 °C or less. As noted above, the average pre-shipment burst volumes and pressure were unusually high, higher in fact than the average initial values for the condoms used in the stability studies. The pre-shipment tests were carried out approximately one month of the condoms had been manufactured. It is possible that at this early stage the network structures within the condoms had not had adequate time to mature. It is probable therefore that a considerable portion of changes in burst properties observed during the shipping trials were due to continued maturation of the rubber matrix and not a result of temperature excursions during shipping. Confirming this retrospectively is not possible.

Chapter 4: Discussion

Although stability studies on both types of condom types used in these shipping studies confirmed they met the requirements that support a 5-year shelf life, the results from the shipping studies suggested that the condoms in the Ugandan study, which were manufactured in Thailand, appeared more stable than those manufactured in India and shipped to Nigeria. However, as indicated above, this could be due to the timing of the pre-shipment tests in the case of the Nigerian samples. These tests were conducted generally within a month of the condoms being manufactured whereas samples used in stability studies must have been stored in bulk for the maximum period permitted by the manufacturer's SOPs in order to comply with the requirements of ISO 4074:2015.

In the case of the Nigerian shipments there was a reasonably strong correlation between increasing values for MKT with rising peak temperatures (the coefficient of determination, R^2, was 0.83). This correlation, however, did not follow through to the relationships between the changes in burst properties and MKT. There were only weakly correlated trends for increasing burst volumes ($R^2 = 0.124$) and decreasing burst pressures ($R^2 = 0.045$) with higher MKTs during shipping.

In the case of the Ugandan shipments the correlation between MKTs and peak temperatures was only moderate ($R^2 = 0.490$). The correlation between changes in burst volume and pressure were weak to very weak ($R^2 = 7 \times 10^{-6}$ for volume and $R^2 = 0.076$ for pressure). The weaker correlations in these cases might be due to the lower values of the peak temperatures recorded (the maximum recorded temperature in the Nigerian trial was compared to 43.8 °C compared to 48.0 °C in the Ugandan study).

Chapter 5: Conclusions

Based on these shipping studies the following major conclusions can be drawn:

1. The MKTs recorded in these studies were only marginally higher than 30 °C even when peak temperatures rose as high as 48 °C. The highest MKT recorded in the Ugandan shipments was 30.3 °C and in the Nigerian shipments was 32.0 °C. Since these MKTs were only marginally higher than the 30 °C temperature specified as the reference temperature for conducting stability studies on condoms the impact of temperature excursions on the shelf lives of the condoms would be expected to be minimal.

2. After shipment all of the lots remained in full compliance with the requirements of ISO 4074:2015. In most cases statistically significant changes in burst properties were observed but the post-shipment values remained comfortably above the lower 98.5% one-sided confidence limits for burst volume and pressure. The results confirm that the impact of shipping on the risk of the lots failing to comply with the requirements of ISO 4074:215 appears negligible. Some deterioration in average burst values for the Nigerian shipments were observed but the primary cause of this appears to be more likely attributable to properties of the condoms than due to the temperature excursions experienced during shipping.

3. The current requirements specified in ISO 4074:2015 relating to the determination of the shelf lives of condoms do not necessarily provide direct information about the stability of condoms during shipping. Both types of condoms used in the reported studies met the ISO 4074:2015 requirements for a 5-year shelf life but temperature excursion experienced during shipping appeared to have a significantly larger impact on the properties of one of the condom types compared to the other. A test that can assess the impact of temperature excursions during shipping on the properties of condoms could assist procurement agencies securing condoms for countries with hot climates.

4. Monitoring the MKT during condom shipments is a relatively simple and cost-effective method of assessing if consignments have been exposed to excessive temperature excursion during shipping that might affect the properties their condoms. If the MKT exceeds a specified temperature, for example 35 °C then further testing of randomly selected lots from the consignment could be undertaken to ensure the condoms are of suitably quality for within country distribution.

Chapter 6: Attachments:

6.1: Tables 1 and 2 summarising the data logger outputs during the shipments

6.2: Charts 1 to 4 showing the ratios of burst properties after compared to before shipping

Table 1: Data Logger Output Ugandan Shipments

Lot Number	MKT (° C)	Max Temp (° C)	Min Temp (°C)
17PN892	30.1	43.0	23.0
17PN895	28.6	31.4	23.6
17PN904	28.3	31.5	23.6
17PN907	28.8	39.6	
17PN911	28.2	31.3	21.6
17PN915	29.5	41.9	18.3
17PN916	27.9	40.7	21.7
17PN920	28.1	31.9	22.0
17PN924	29.7	41.1	21.7
17PN927	28.2	32.6	23.6
17PN936	28.2	31.2	21.9
17PN939	29.3	41.6	21.4
17PN940	29.6	42.2	21.5
17PN944	28.5	32.8	20.9
17PN948	29.6	41.9	19.3
17PN951	28.2	31.2	21.8
17PN956	29.7	39.6	21.6
17PN960	27.4	31.6	23.2
17PN964	30.2	41.7	20.4
17PN967	28.5	32.5	22.2
17PN979	28.5	36.5	21.8
17PN980	30.3	43.8	19.3
17PN995	28.4	38.9	20.3
17PN996	28.3	39.1	
17PN999	28.2	31.0	
17PN1003	28.3	33.5	23.6
17PN1004	28.6	38.6	21.8
17PN1013	29.8	42.4	21.9
17PN1017	28.3	31.7	24.5
17PN1085	29.9	31.8	22.1
17PN1085	28.3	31.9	19.4
17PN1092	29.1	38.7	21.3
17PN1096	29.2	35.3	21.9
17PN1100	29.8	41	21.9
17PN1101	28.3	32.3	20.9
17PN1101	28.6	42.1	23.2
17PN1105	28.7	32.1	24.5
17PN1108	28.2	32.3	22.7

Table 2: Data Logger Output Nigerian Shipments

Temperature Logger Details				Temperatures (°C)			
Logger No.	**Shipment**	**Pos. in Cont.**	**Pos. in Pallet**	**Average**	**MKT (calculated)**	**Min**	**Max**
72070014486	2	Top	Top	30.7	31.9	17.4	46.1
72070014479	1	Top	Top	29.4	30.6	15.1	43.4
72060014244	1	Top	Top	30.1	31.2	15.3	43.2
72070014483	2	Top	Top	30.6	31.8	17.4	48.0
72070014480	2	Top	Top	30.8	32.0	18.3	45.6
72060014250	1	Top	Top	28.7	29.5	14.9	42.4
72060014253	1	Top	Top	29.9	30.7	18.6	44.0
72060014247	1	Top	Top	28.7	29.3	19.0	40.8
72070014482	2	Bottom	Bottom	27.8	28.3	19.2	36.3
72070014492	2	Middle	Middle	29.9	30.4	21.5	43.1
72070014478	1	Middle	Middle	28.6	29.3	15.6	34.6
72060014249	1	Middle	Middle	28.4	29.0	15.3	33.7
72060014256	1	Bottom	Bottom	28.1	28.6	15.0	34.1
72060014243	1	Middle	Middle	29.2	29.7	16.6	33.1
72060014234	1	Bottom	Bottom	28.4	29.0	15.4	33.5
72060014248	1	Bottom	Bottom	27.9	28.4	14.7	33.8
72070014488	2	Bottom	Bottom	27.5	28.0	18.2	34.0
72070014481	2	Middle	Middle	28.3	28.7	19.7	35.0
72070014485	2	Bottom	Bottom	27.7	28.1	18.7	34.7
72060014252	1	Middle	Middle	28.9	29.3	18.7	34.5
72070014487	2	Middle	Middle	28.4	28.8	20.4	33.1
72070014484	2	Middle	Middle	28.1	28.5	19.5	33.8
72060014245	1	Bottom	Bottom	28.0	28.4	18.9	33.5
72060014251	1	Bottom	Bottom	28.3	28.6	18.6	32.3
72070014493	2	Bottom	Bottom	29.5	29.7	23.3	34.7
72070014491	2	Top	Top	29.8	30.1	24.2	35.0

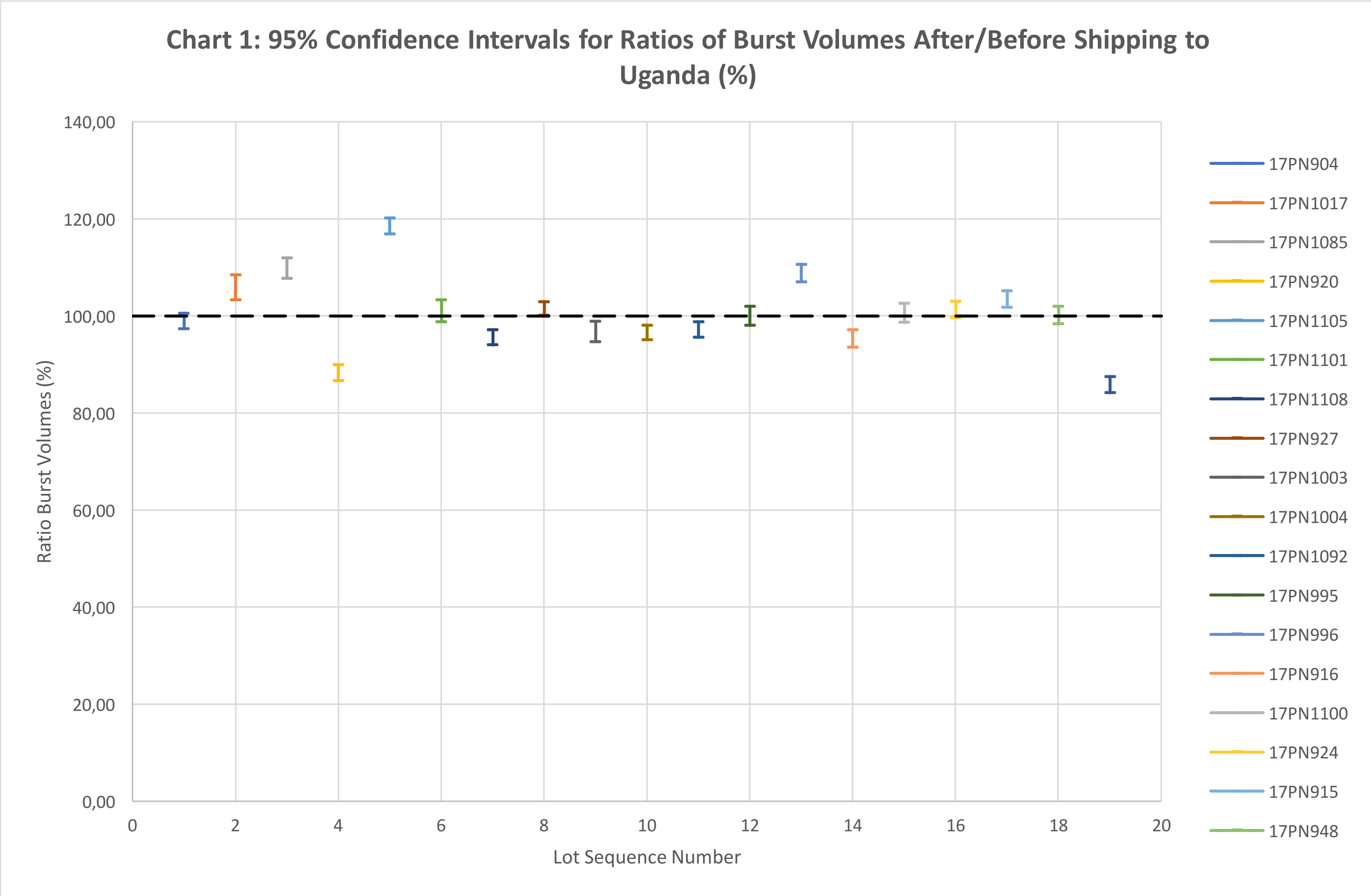
Chart 1: 95% Confidence Intervals for Ratios of Burst Volumes After/Before Shipping to Uganda (%)
Ratio Burst Volumes (%)
140,00
120,00
100,00
80,00
60,00
40,00
20,00
0,00
0
2
4
6
8
10
12
14
16
18
20
Lot Sequence Number
17PN904
17PN1017
17PN1085
17PN920
17PN1105
17PN1101
17PN1108
17PN927
17PN1003
17PN1004
17PN1092
17PN995
17PN996
17PN916
17PN1100
17PN924
17PN915
17PN948

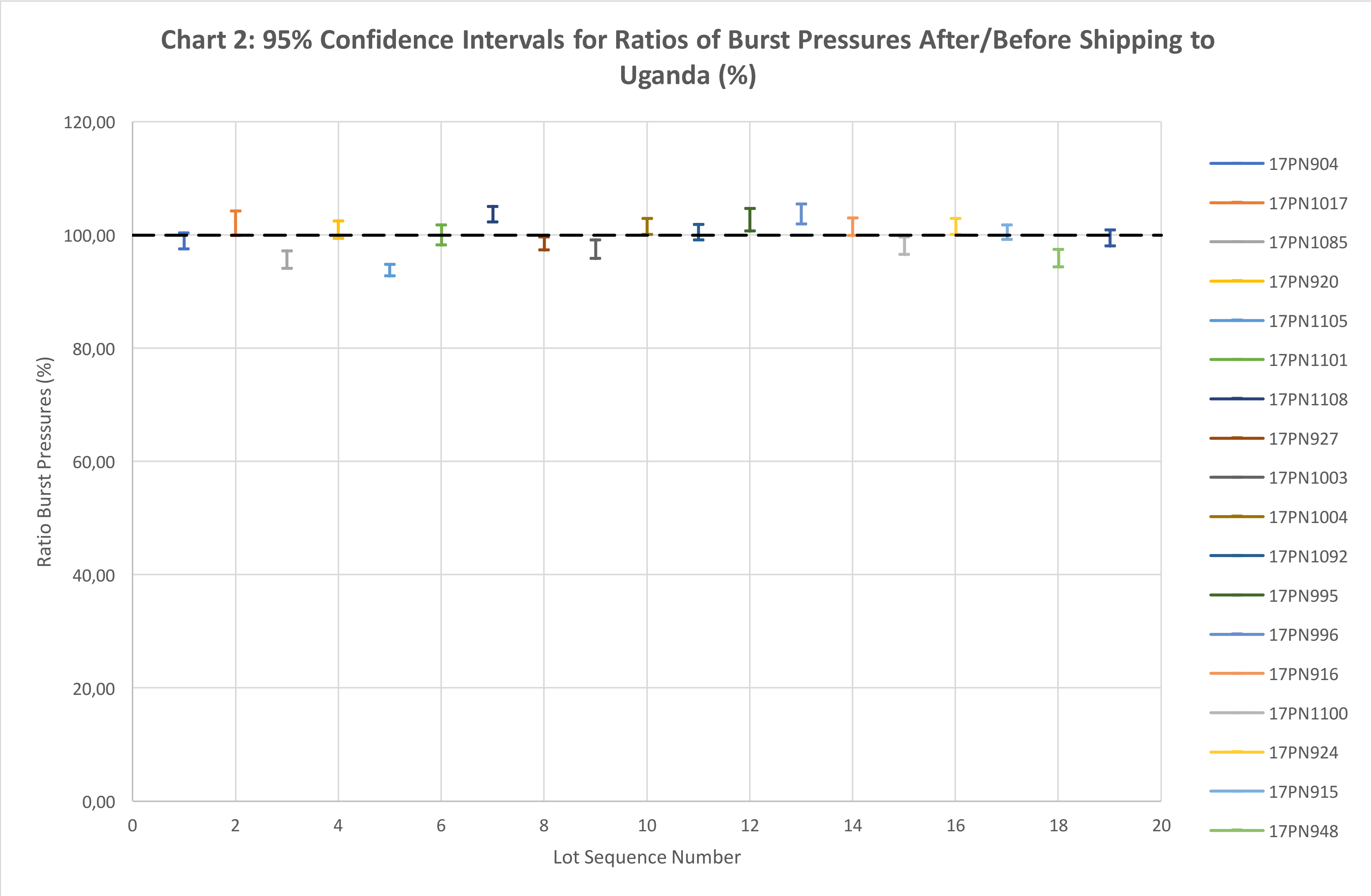
Chart 2: 95% Confidence Intervals for Ratios of Burst Pressures After/Before Shipping to Uganda (%)
Ratio Burst Pressures (%)
120,00
100,00
80,00
60,00
40,00
20,00
0,00
0
2
4
6
8
10
12
14
16
18
20
Lot Sequence Number
17PN904
17PN1017
17PN1085
17PN920
17PN1105
17PN1101
17PN1108
17PN927
17PN1003
17PN1004
17PN1092
17PN995
17PN996
17PN916
17PN1100
17PN924
17PN915
17PN948

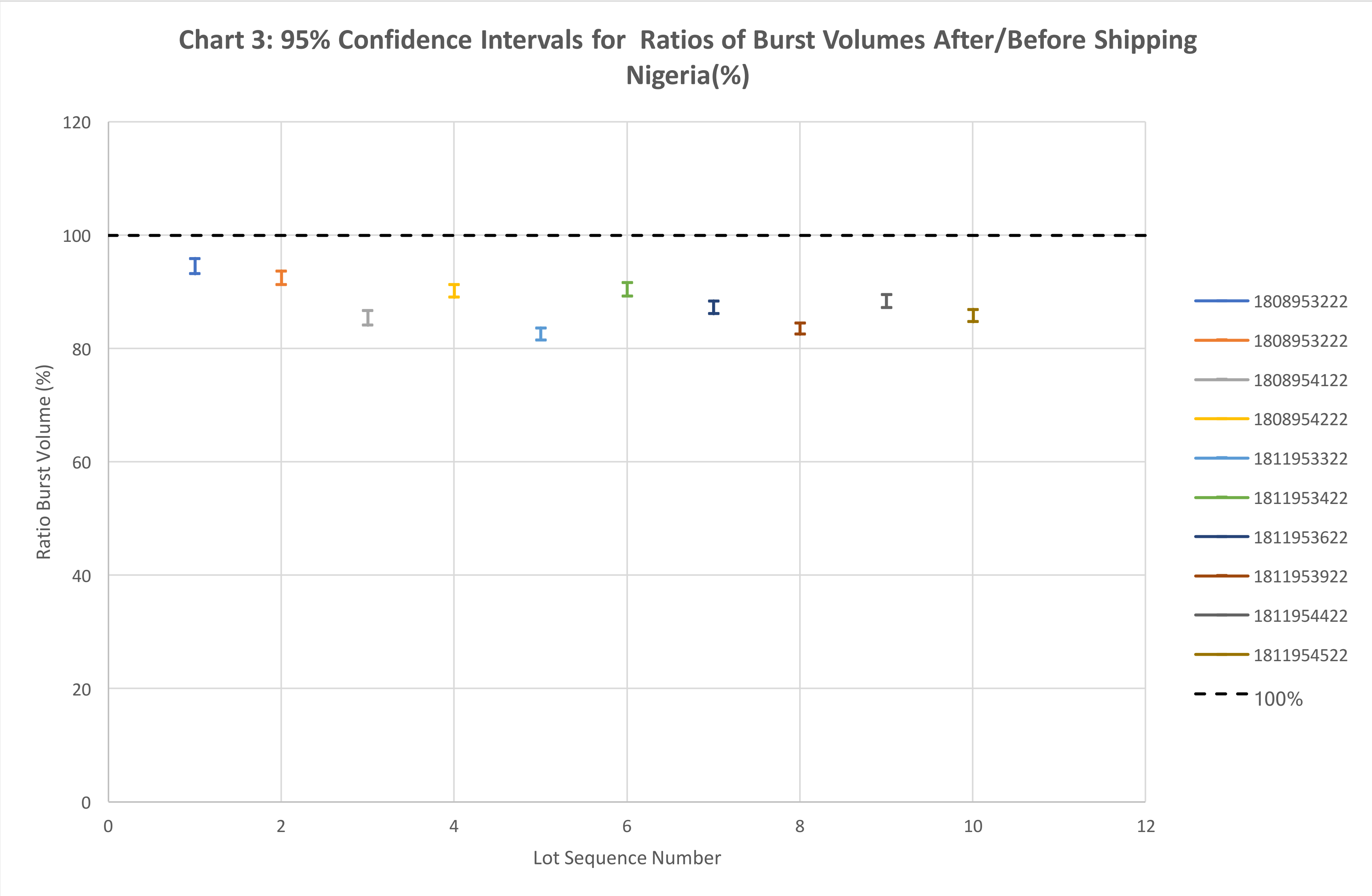
Chart 3: 95% Confidence Intervals for Ratios of Burst Volumes After/Before Shipping Nigeria(%)
120
100
80
60
40
20
0
Ratio Burst Volume (%)
0
2
4
6
8
10
12
Lot Sequence Number
1808953222
1808953222
1808954122
1808954222
1811953322
1811953422
1811953622
1811953922
1811954422
1811954522
100%

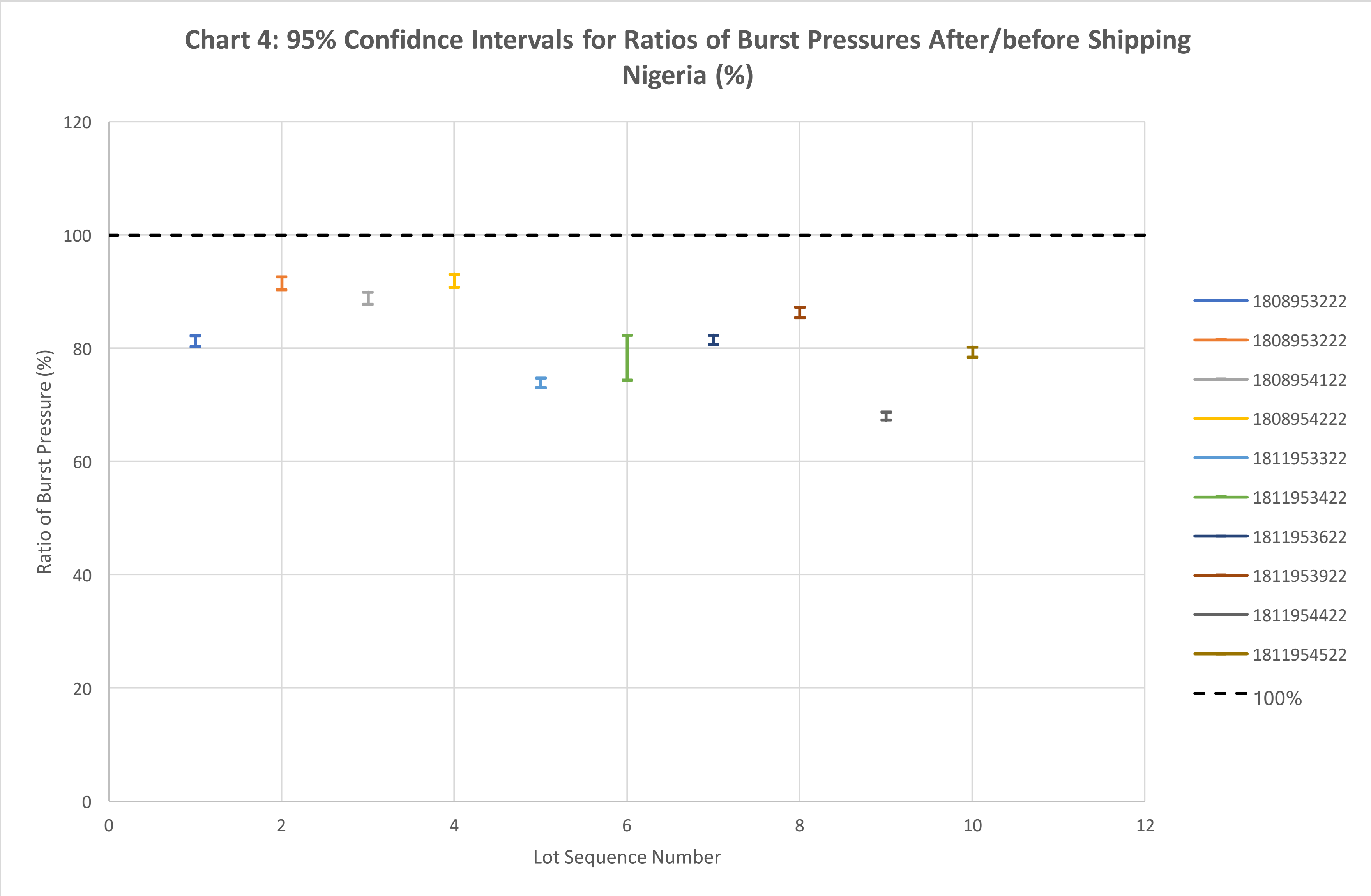

Chart 4: 95% Confidnce Intervals for Ratios of Burst Pressures After/before Shipping Nigeria (%)
Ratio of Burst Pressure (%)
120
100
80
60
40
20
0
0
2
4
6
8
10
12
Lot Sequence Number
1808953222
1808953222
1808954122
1808954222
1811953322
1811953422
1811953622
1811953922
1811954422
1811954522
100%

Chapter 7: REFERENCES

1. WHO Technical Report Series, No. 1010, 2018 Annex 10 Stability testing of active pharmaceutical ingredients and finished pharmaceutical products. https://database.ich.org/sites/default/files/Q1F_Stability_Guideline_WHO_2018.pdf
2. J D Haynes. Worldwide Virtual Temperatures for Product Stability Testing. J Pharm Sci, 60 (6) 927-929, 1971. https://doi.org/10.1002/jps.2600600629
3. International Conference on Harmonization (ICH) guideline: "Stability Testing of New Drug Substances and Products Q1A (R2). https://database.ich.org/sites/default/files/Q1A%28R2%29%20Guideline.pdf
4. ISO 4074:2015 Natural rubber latex male condoms — Requirements and test methods https://www.iso.org/standard/67615.html
5. Arrhenius, S. A. (1889). "Über die Reaktionsgeschwindigkeit bei der Inversion von Rohrzucker durch Säuren". Z. Phys. Chem. 4: 226–48. doi:10.1515/zpch-1889-0116
6. WHO/United Nations Population Fund technical specifications for male latex condoms. In: WHO Expert Committee on Specifications for Pharmaceutical Preparations: fifty-fourth report. Geneva: World Health Organization; 2020: Annex 10 (WHO Technical Report Series, No. 1025). https://www.who.int/publications/i/item/978-92-4-000182-4
7. ISO/IEC 17025:217 Testing and Calibration Laboratories.https://www.iso.org/ISO-IEC-17025-testing-and-calibration-laboratories.html
8. Fieller, EC. The biological standardization of Insulin. Suppl to J R Statist Soc. 1940; 7:1–64.