Lütke Entrup, Matthias; Tiedge-Arnold, Edwin; Perret, Jens K.

Article

Probability-based management of filling quantities – Development of a procedure to optimize filling quantities in pre-packages based on German regulations for pre-packaged goods

ISM Research Journal

Provided in Cooperation with:
International School of Management (ISM), Dortmund

Suggested Citation: Lütke Entrup, Matthias; Tiedge-Arnold, Edwin; Perret, Jens K. (2019) : Probability-based management of filling quantities – Development of a procedure to optimize filling quantities in pre-packages based on German regulations for pre-packaged goods, ISM Research Journal, ISSN 2627-4647, readbox unipress, Münster, Vol. 6, Iss. 1, pp. 1-18

This Version is available at:
https://hdl.handle.net/10419/324705

Lütke Entrup, Matthias; Tiedge-Arnold, Edwin; Perret, Jens K.

Probability-based management of filling quantities – Development of a procedure to optimize filling quantities in pre-packages based on German regulations for pre-packaged goods

Abstract

In a competitive environment characterised by tight margins and the increasing cost of raw materials, many food producers are aiming to identify additional cost reduction measures. To that respect, the filling quantity of pre-packaged goods is of major interest, as a reduction of this quantity will directly improve the cost of a product. However, the placing on the market of pre-packages is amendable to the provisions of the pre-packaging regulation. This creates conflicting priorities for the manufacturers: meet these requirements, but avoid unnecessary costs of material.

This study offers producers of pre-packaged goods a procedure to evaluate the relative and financial risk attributed to an optimization of filling quantities; where it takes into particular consideration the legislative framework in Germany.

A case study included, exemplifies the use of this procedure and reports on the possible financial savings.

Keywords:

Probability-based management, pre-packaging, pre-packaged goods, Mess- und Eichgesetz, Fertigpackungsverordnung, Office of Weights and Measures, food-processing industry, filling processes

1 Introduction

Due to increasing downsizing attempts by manufacturers with regard to package fillings since the liberalisation of the package filling quantities in the European Union (EU) in 2007 (EU 2007) downsizing as a marketing strategy has received a bad reputation (Leibinger 2017). However, the use of downsizing as a measure to reduce costs did not arise in the wake of the EU liberalisation but has already been discussed much earlier as studies like Adams et al. (1991) and a number referred to by Leibinger (2017) can attest to. From a similarly early date on studies like Adams et al. (1991) warned about the possible negative side effects on the producer's reputation and thus his sales. This argument can be backed by psychological insights like those discussed in Kahneman et al. (1986) that consumers react negatively to price increases which they perceive as unfair, meaning the price is increased without them receiving any kind of compensation for the additional costs.

Thus, a need arises for producers to come up with a strategy to downsize in regards to quantity internally while externally the façade that prices and quantities remain unchanged still holds. The obvious decision in this situation would be to decrease the inputs, these being the filling quantities of the pre-packaged goods. However, the placing on the market of pre-packages in Germany is amendable to the German pre-packaging regulation. The legal requirements of this provision are to be implemented by the manufacturers; the Office of Weights and Measures ("Eichamt", OWM) of the respective federal states controls the compliance to these provisions. This creates conflicting priorities for the manufacturers to meet the requirements of these provisions on the one hand and on the other to avoid unnecessary costs of material.

These are the aspects where the following study becomes particularly relevant. Most production processes and those supplying pre-packaged goods in particular, are highly stochastic in nature. Even though, innovative machinery can help reduce the variance the stochastic nature of these processes may not be removed. The stochastic nature of the production process results in unnecessary waste in the production process as in many enterprises, the controlling of filling quantities is executed solely by using mean values, the spread of these values, as well as the specific characteristics of the relevant OWM's testing methods, are not or only partially considered when managing filling quantities. Therefore, a procedure is proposed which generates a filling quantity risk profile per item, based on historical filling, data thus allowing a focused optimization of the filling processes resulting in a decrease of required inputs. The use of the risk profile for a specific production process allows for a quantification of the probability attributed to breaching regulations.

However, although this study is not the first to concern itself with the risk profile of company's packaging processes (Fincke and Krauss 1967), it is the first that considers in particular the concrete regulations of the German OWM in the most recent versions of the Weights and Measures Act ("Mess- und Eichgesetz") (AG Mess- und Eichwesen 2013) as well as in the pre-package regulation ("Fertigpackungsverordnung") (FertigPackV 18.12.1981).

This is particularly important, as the number of companies that have breached any of the regulations of the OWM and are thus liable for fines has increased over the last number of years (Ernährungsumschau 2008; MessEG 2013; AG Mess- und Eichwesen 2014). The immediate need for a tool to assess the related risks is therefore apparent.

As Al-Sultan and Pulak (2010) already state in their introduction neither this study nor the one by Al-Sultan and Pulak (2010) are the first to study this phenomenon. However, while most studies, Darwish et al. (2013), Tahera et al. (2008), Chen and Lai (2007) or Chen (2004), primarily concern themselves with strategies for setting the mean, this study focusses on the risks attributed to a situation where the mean already has been determined by outside decisions. Additionally, this study tackles the underlying specific problem from an empirical background whereas the other studies provide a general optimization model.

The legislative background of Germany with regard to pre-packaged goods is presented in the second section of this paper. The focus in this section lies on determining the regulations that limit the filling process and thus determine the risk attributed to a decrease in filling quantities.

Section 3 develops this procedure by determining the risk at all three steps in the tests conducted by the OWM and as a result presents an approximation of the comprehensive risk attributed to setting a specific mean for the production process.

Finally, the fourth section presents as a case study, the application of the deduced risk measures by using a sample of 38 types of chocolate bars with a sample size of 50 each. Not only are the attributed risks discussed in detail but possible savings and costs are calculated and the procedure is thus evaluated in financial terms.

The fifth section acts as a conclusion.

2 Provisions of the pre-packaging regulation

2.1 Requirements for filling quantities of pre-packages

The German requirements for manufacturing pre-packages are regulated, inter alia, in the Weights and Measures Act ("Mess- und Eichgesetz", MessEG) as well as in pre-package regulations ("Fertigpackungsverordnung", FertigPackV). As the legislation on pre-packages was unified by the European Directive 76/211/EEC of 20 January 1976, similar regulations exist in all countries of the European Union and even beyond (e.g. in Switzerland). In accordance with § 43 (1) MessEG, pre-packages may only be manufactured, if the nominal quantity is declared, the filling quantity complies with the set requirements and the pre-package is fitted with the necessary descriptions, inscriptions and symbols. In accordance with § 44 (1) MessEG, the Federal Government is authorised to enact provisions of itemization and execution via a respective ordinance. In Germany, this took effect by enacting the FertigPackV. For one, the requirements that the pre-package must fulfil is to be manufactured and placed on the market are described. Secondly, the criteria of the gauging offices that control the compliance with the requirements must be specified (see 2.2).

Table 1: Tolerable negative error acc. to § 22 (3) FertigPackV

Normal quantity in grams or millilitres	Total negative error	
	As a percentage of nominal quantity	g or ml
5 to 50	9	-
from 50 to 100	-	4,5
from 100 to 200	4,5	-
from 200 to 300	-	9
from 300 to 500	3	-
from 500 to 1,000	-	15
from 1,000 to 10,000	1,5	-

According to the pre-packaging regulation, the filling quantities of pre-packages have to fulfil three core requirements:

(1) On average, all sold packages must meet the nominal filling quantity (indicated on the packaging) to be permitted to be manufactured (§ 22 (1) 1 FertigPackV) and be placed on the market (§ 22 (2) 1 FertigPackV).

(2) Additionally, only a maximum of two percent of all sold packages may fall below a defined lower limit of the filling quantity, the so-called "Technical Lower Limit 1" ("Technische Untergrenze 1", TU1), acc. to § 22 (3) FertigPackV. The permissible tolerance of TU1 depends on the nominal filling quantity (see Table 1).

(3) Finally, no sold package must fall below another defined lower limit of the filling quantity, the so-called "Technical Lower Limit 2" ("Technische Untergrenze 2", TU2), acc. to § 22 (2) FertigPackV. TU2 is double the deviation of TU1.

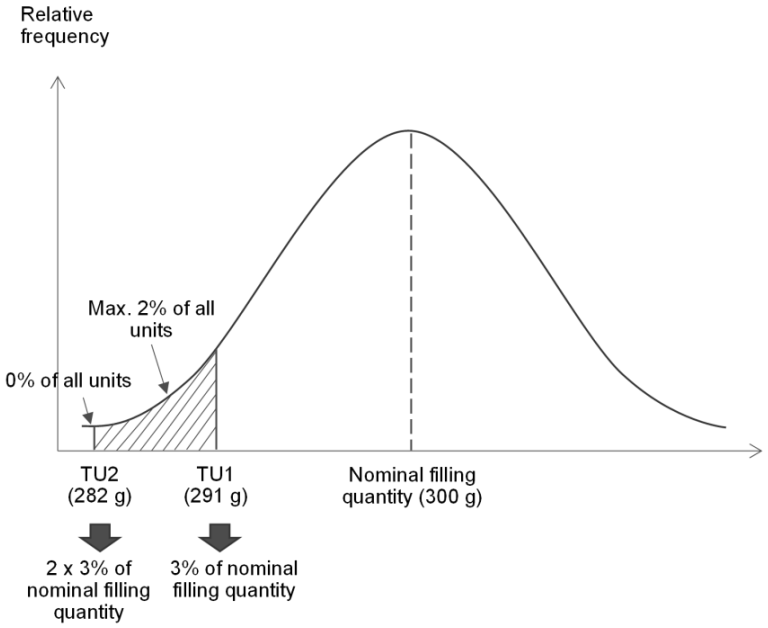

Figure 1: Permissible minus deviations at a nominal filling quantity of 300g

Using the example of an article with a declared nominal filling quantity of 300g means that 2% of all packages may weigh less than 291g and no package may weigh less than 282g (see Figure 1).

2.2 Examination procedure of filling quantities

The compliance to the legal provisions of the FertigPackV is examined by the OWM with the use of random samples. More detailed regulations are given in Appendix 4a of the FertigPackV. According to that, the examination is in general to be performed in the filling plant of the producer. It can also take place in a warehouse or on the premises of the responsible authority.

The following observations have to be made during an audit by the OWM:

(1) The determination of the lot size,

(2) The determination of the associated random sample (type, scope, and parameters),

(3) The determination of the mean of the random sample, and

(4) The determination of the compliance with the permissible negative deviations.

(1) The determination of the lot size

The basis for the determination of the random sample is the lot size in which a product is typically produced. In this case, the larger the lot size in production, the larger the sampling scope. According to Appendix 4a (3) FertigPackV, the lot size equates to the 'total volume of pre-packages with similar nominal filling quantity, same appearance and same production, filled at the same location. The lot size is limited … by the number of produced pre-packages in one hour.'

(2) The determination of the associated random sample (type, scope and parameters)

Generally, the FertigPackV differentiates between destructive and nondestructive testing procedures. When using the destructive testing method, the product is opened and cannot be placed on the market after weighing. To reduce the economic loss for the producers, the sampling size is smaller in this case. If the package weight is predominantly standardized and small in relation to the nominal filling quantity, the non-destructive testing method is used. In this case, the sampling size is significantly larger. After the random sample type is set, the appropriate sampling scope and sampling parameters should then be determined. This is illustrated by the use of a normal, nondestructive, double sampling inspection with a lot size of >= 3,201 packages, which is standard in the production of consumer goods (see Table 2).

Table 2: Testing characteristics of a normal, nondestructive, double sampling inspection

N	Order	n1, n2	nk	c1, ck	d1, dk	k
100 to 500	1st	30		1	3	0.503
	2nd	30	60	4	5	0.344
501 to 3200	1st	50		2	5	0.379
	2nd	50	100	6	7	0.262
3201 and over	1st	80		3	7	0.295
	2nd	80	160	8	9	0.207

Explanation of the parameters:

N	Lot size
n	Sample size
n1, n2	Sample size of first or second sample
nk	Accumulated sampling size = sum of sample size of 1st and 2nd sample
c	Acceptance criterion
c1, ck	Acceptance criterion of 1st or accumulated sample
d	Rejection criterion
d1, dk	Rejection criterion of 1st or accumulated sample
k	Factor for the calculation of the confidence interval ($k = t/\sqrt{n}$ where $t = t_{0,995;n}$ of the one-sided student-t distribution)
xi	Filling quantities i = 1,…, n1 or i = 1,…, nk of the packages in the sample
$\bar{x}$	Mean (arithmetic mean) of the filling quantities in the sample

As can be seen from Table 2, with a lot size of more than 3,200 packages, a sample of 80 packages should be weighed. In this case, the entire package (content and packing) is weighed, which corresponds to the gross weight. Then, the average tare weight is deducted to determine the net filling weight.

(3) The determination of the mean of the random sample

The next step is to determine the mean of the net weights. This mean of the sample ($\bar{x}$) is increased by the factor k s according to Appendix 4a (7) FertigPackV, where the k-value can be deducted from Table 2 and s equates to the standard deviation of the weighted sample. As a result, the corrected mean ($K = \bar{x} + k \cdot s$) has to match the declared nominal filling quantity at least, to fulfil the requirements of the FertigPackV.

(4) The determination of the compliance with the permissible negative deviations.

The compliance with the permissible negative deviations is determined by the acceptance criterion c1 or ck and the rejection criterion d1 or dk. Three cases have to be differentiated:

- If the number of pre-packages that exceed the permissible negative deviation (show a weight lower than TU1) is equal to or smaller than the first acceptance criterion c1 in the first sample, the FertigPackV's requirements are fulfilled.
- If this number is equal to or larger than the first rejection criterion d1, these requirements are not fulfilled.
- If this number is between the first acceptance criterion c1 and the first rejection criterion d1, a second sample with the scope indicated in Table 2 has to be analysed. The respective number of pre-packages of the first and second sample that exceeds the permissible negative deviation is to be accumulated. If the cumulated number of pre-packages is equal to or smaller than the accumulated acceptance criterion ck, the requirements are fulfilled. If the cumulated number is equal to or larger than the accumulated rejection criterion dk, the requirements are not fulfilled.

Additionally, no pre-package may exceed double of the permissible negative deviation (TU2).

Overall, companies that (repeatedly) fail to pass examinations may face severe fines. In extreme cases, the OWM is entitled to enforce a temporary closure of production.

3 Development of a procedure to optimize filling quantities

3.1 Procedure outline

As mentioned before, companies are generally facing the challenge of fulfilling all requirements of the FertigPackV on the one hand, and on the other not to overfill the products and hence to reduce the costs of material. For this purpose, the definition of an article-specific target filling quantity is decisive for the filling team on the floor, which is based on a quantitative method. Here, the company must define which residual probability it is willing to accept for not passing the OWM testing. If a company does not eliminate all pre-packages below the nominal filling quantity, this residual probability will never be zero, because it is theoretically possible, that the OWM selects these under-filled packages as samples in the examination. Every company has a different tolerance for this risk threshold. A risk-averse company perceives a probability of 0.5%

as unpleasantly high while another company is willing to accept a probability of maybe 3% or more.

The procedure is based on the following assumptions:

- The net filling weights are normally distributed and can be described by using the mean and standard deviation.
- Historical weight data are representative for future filling processes.
- The standard deviation of the filling process can only be reduced in the medium- to long-term and with a higher effort. On the contrary, the mean of the net filling weight (desired filling quantity) can be decreased or increased in a timely manner.
- The standard deviation of the net filling quantity is equal to the standard deviation of the OWM samples.

The first step is to calculate the probability to not passing a OWM testing with the current filling processes. For that, the probabilities of not fulfilling individual requirements of the FertigPackV are determined (compliance to nominal filling quantity, compliance to TU1, compliance to TU2). The total probability of not passing the requirements of the sample tests is finally determined based on these three probabilities.

In the second step, the mean of the net filling weights is gradually altered until the desired target probability is obtained. This new mean will then define the target filling quantity of the production. Additionally, the effect of a reduced standard deviation of the filling weights can be determined with the given total probability.

3.2 Probability of compliance with nominal filling quantity

In this as well as the following three chapters, it is implied that the mean of the underlying distribution (μ) does not correspond to the nominal filling quantity (NF).

Firstly, the probability of the modified mean ($K = \bar{x} + k \cdot s$) being smaller than the nominal filling quantity (NF) has to be determined. With a slight modification, this requirement can be written as:

$K = \bar{x} + k \cdot s < NF$ or

$\bar{x} < NF - k \cdot s$

The second presentation format of the requirement matches the H_0-hypothesis of a one-sided t-test. Therefore, the probability that this situation does not occur and hence the probability that the sample does not fulfil the criterion/requirement of the FertigPackV results in the following:

$$P(A) = 1 - t^{-1}\left(\sqrt{n}\frac{K - NF}{s}\right)$$

Here, t^{-1} describes the cumulated distribution function of the student-t-distribution. For simplification, the t-distribution can be approximated by the normal distribution, if the sample size is at least n=30 (because 30 is the smallest sample size in a non-destructive sample, the approximation is always valid), thus the respective probability can be determined by:

$$P(A) = 1 - \Phi\left(\sqrt{n}\frac{K - NF}{s}\right),$$

where Φ describes the distribution function of the standard normal distribution.

3.3 Probability of compliance with acceptance criterion

The probability of breaching the acceptance criterion can be determined with three steps. The total number of products expected to violate the limit of TU1 (with regard to the total lot) results in:

$$A = \left\lceil N \cdot \Phi\left(\frac{TU1 - \mu}{s}\right)\right\rceil$$

The brackets $\lceil . \rceil$ stand for the Gaussian brackets which ensure that the result will always be rounded up and therefore guarantee an integral value for A. When analyzing the packages violating TU1, one has to consider that each of these packages is tested only once. Even though the testing procedure is non-destructive, a hypergeometric distribution has to be selected, as the test is performed without putting the tested packages back. The underlying probabilities are thus changing with every tested package. Accordingly, the probabilities that the number of packages violating the limit of TU1 is equal to or smaller than c1 ($P(B_1)$) or bigger than or equal to d1 ($P(B_2)$) can be determined in the following manner:

$$P(B_1) = \sum_{i=0}^{c1} \frac{\binom{A}{i} \cdot \binom{N - A}{n1 - i}}{\binom{N}{n1}}$$

$$P(B_2) = 1 - \sum_{i=0}^{d1-1} \frac{\binom{A}{i} \cdot \binom{N - A}{n1 - i}}{\binom{N}{n1}}$$

Congruous with that, the probability arises that the number of failing packages is bigger than c1 but smaller than d1, which makes an increase in sampling size necessary as a residual probability with regard to the two above-mentioned occurrence probability:

$$P(B_3) = 1 - P(B_1) - P(B_2)$$

After the sample size is increased from n1 to nk, the probability that the number of failing packages is bigger than or equal to the limit dk can be calculated:

$$P(B_4) = 1 - \sum_{i=0}^{dk-1} \frac{\binom{A}{i} \cdot \binom{N-A}{nk-i}}{\binom{N}{nk}}$$

Because at this point it is presumed that the shift from n1 to nk already took place, it is not necessary to revert to the conditional probability. The total probability of a violation of this criterion in the FertigPackV is:

$$P(B) = P(B_2) + P(B_3) \cdot P(B_4|B_3)$$

As when determining $P(B_4)$ the precondition of this situation occurring in the first place is not considered, it is necessary to factor it in at this point. It follows that the occurrence of violating the OWM requirements in the second step is dependent violating them in the first step, because on the one hand all elements of the first sample are part of the second bigger sample. On the other hand, the limits of the second sample are relatively tighter than the limits of the first sample. For practically mastering this problem, the easiest possibility is to make an estimation of the results by implying stochastic independence. In this case

$$P(B) = P(B_2) + P(B_3) \cdot P(B_4)$$

describes an approximation of the actual probability.

While in this case, it cannot be certain if the actual probability is over- or underestimated, the following formula describes a possible conservative upper limit for the probability:

$$P(B) = P(B_2) + max\{P(B_3);\ P(B_4)\}$$

A more accurate solution would only be determined empirically by reformulating the probability as:

$$P(B) = P(B_2) + P(B_3) \cdot \frac{P(B_4 \cap B_3)}{P(B_3)} = P(B_2) + P(B_4 \cap B_3)$$

Subsequently, the probability $P(B_4 \cap B_3)$ can be approximated empirically by determining how many samples fail to fulfil both criteria.

3.4 Probability of compliance with TU2

When calculating the probability of complying with TU2, two cases can be singled out in general:

If during the filling process an automated mechanism for the rejection of under-filled pre-packages is used, the probability to fall below TU2 can be rated as being zero, as these packages are not placed on the market. In this case, however, the probabilities P(A) and P(B) would change, because the assumed normal distribution would have to be replaced by a cut normal distribution (the distribution function of a cut normal distribution is given as $\Psi(\mu, s; K)$, where K indicates the point of cutting). This is especially essential for the distribution functions Φ(μ, s; K) or Φ(μ, s; TU1). The corrected version of the distribution functions are:

$$\Phi(\mu, s;\ K)\ \rightarrow\ \Psi(\mu, s; K) = \frac{\Phi\left(\frac{\mu - K}{s}\right) - \Phi\left(\frac{\mu - TU2}{s}\right)}{1 - \Phi\left(\frac{\mu - TU2}{s}\right)}$$

$$\Phi(\mu, s;\ TU1)\ \rightarrow\ \Psi(\mu, s; TU1) = \frac{\Phi\left(\frac{\mu - TU1}{s}\right) - \Phi\left(\frac{\mu - TU2}{s}\right)}{1 - \Phi\left(\frac{\mu - TU2}{s}\right)}$$

If this technology is not available, the probability of falling below TU2 is calculated with the density function of the normal distribution, where the number of packages violating the limit of TU2 is determined in analogy to part 3.3 as:

$$A = \left\lceil N \cdot \left(1 - \Phi\left(\frac{\mu - TU2}{s}\right)\right)\right\rceil$$

The number is rounded up with the use of the Gaussian brackets as before. The probability of at least one package of the sample violating TU2 is determined with the hypergeometric distribution (in analogy to 3.3) as:

$$P(C) = 1 - \frac{\binom{A}{0} \cdot \binom{N - A}{nk}}{\binom{N}{nk}}$$

This probability can be simplified to:

$$P(C) = 1 - \frac{\binom{N - A}{nk}}{\binom{N}{nk}}$$

3.5 Calculation of overall probability

For calculating the total probability of not passing the OWM tests, it is assumed that either the corrected mean is below the nominal filling quantity, the acceptance value is too low or at least one package falls below the limit of TU2. Mathematically this probability can be described as:

$P(A \cup B \cup C)$ with

$$P(A \cup B \cup C) = P(A) + P(B) + P(C) - P(A \cap B) - P(A \cap C)$$
$$-P(B \cap C) + P(A \cap B \cap C)$$

While the individual probabilities can be directly obtained from the preceding sections, it is neither ensured that the three exclusion criteria are stochastically independent, nor that one of the criteria arises from one of the others. The necessary probabilities of the intersections accordingly cannot be calculated analytically and based on the previously determined probabilities, because even though there can be made assertions in all three cases about the marginal distributions, this is not possible for the underlying joint distribution function.

Here, one needs to take into account that even if the probability P(C) because of its use of appropriate technologies becomes zero, the probability $P(A \cap B)$ still needs to be determined. Even if such technology is not used it has been empirically shown – as also described in the next chapter – that the probability P(C) is negligibly small, especially when combined with an intersection probability, so the total probability is reduced to:

$$P(A \cup B \cup C) = P(A) + P(B) + P(C) - P(A \cap B)$$

In contrast to section 3.3, the probability $P(A \cap B)$ cannot or only with many difficulties can be estimated based on a sample, so an approximation (similar to 3.3) is preferred. This means the total probability can be approximated by one of the two approaches:

$$P(A \cup B \cup C) = P(A) + P(B) + P(C) - P(A) \cdot P(B)$$
$$P(A \cup B \cup C) = P(A) + P(B) + P(C) - min\{P(A);\ P(B)\}$$

It can be assumed that the first probability describes a more conservative estimation while the second is far more liberal and underestimating the actual probability, which means it constitutes a lower limit.

4 Application example

4.1 Sample type and size

The empirical validation of the concept was conducted by an analysis of chocolate bars. Ordinarily, they have a nominal filling quantity of 100g, can be weighed precisely (minimal product adhesions to the packaging) and are commonly available. To consider packages of different production batches, the chocolate bars were purchased at diverse retail chains and in geographically varying retail outlets.

In total, 38 different articles were analyzed (branded products and private labels), by weighing first the whole product and after that only the packaging. The filling quantity can then be determined by the difference of the two values. All analyzed articles have a nominal filling quantity of 100g. The sampling size was set to 50 packages per article, as the standard error of the sample only changes to a lesser extent with an increased sampling size (see Figure 2) and a considerably bigger budget would have been necessary for a larger sampling size. When applying the procedure in an industrial environment, the standard error will be reduced even more.

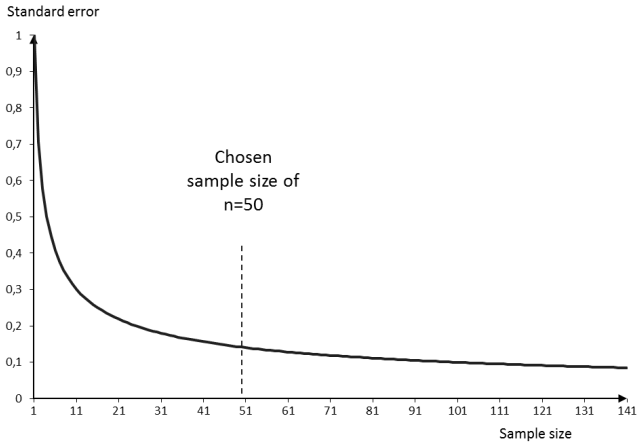

Figure 2: Standard error in relation to sample size

4.2 Analysis results

The distribution of means and the standard deviation of the analysed articles is depicted in Figure 3. In general, a weak positive correlation between the standard deviation and the mean of the filling quantities of the analysed articles can be recognized (coefficient of determination R = 0.3347). This means the manufacturers of chocolate bars are operating with larger filling quantities in case of higher process variances.

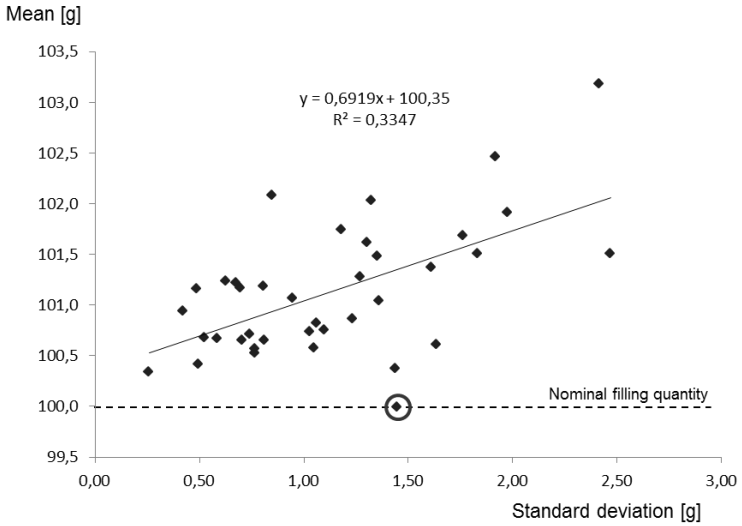

Figure 3: Mean and standard deviation of filling quantities of the analyzed items

Applying the model deduced in section 3.5, the overall probability of failing the OWM test is calculated for each of the 38 brands of chocolate in the sample. The probability of failing the OWM test is under one per mille for 37 of the 38 analyzed items. Only one item (marked) has a high probability (47.1%) to fail the test. As a result, the manufacturers have significant safety buffers because these small probabilities of not passing the test are then ensured by significant overfilling.

In the reverse, possible reductions of the filling quantities per item can be calculated with a given target probability of failing the OWM test. With these target probabilities, the company-specific risk profile can be considered when determining the filling quantities. At a target probability of 2%, the filling quantities of 37 out of the 38 tested items can be reduced by 1.2g on average, given a spread of 0.3g to 3.0g. Based on a raw material price of ca. € 3.00 per kg, the average material cost savings amount to € 0.0036 per bar of 100g. In markets with low margins, this means a significant cost savings potential for the manufacturers.

5 Conclusion

In summary, this study determined the three risk factors for manufacturers of pre-packaged goods in Germany when faced with the regulations set in the "Mess- und Eichgesetz" resulting in a model that has been applied as well to the case of 38 items from the segment of pre-packaged chocolate bars.

Concluding, it is to be noted that the manufacturers of chocolate bars manage their filling quantities with significant safety buffers. A probability-based filling quantity management seems to be applied relatively scarcely. An adjustment of filling quantities with target probabilities which do not to pass the OWM's test enables companies on the one hand to identify risky items and to increase the filling quantities, on the other, in this way an unnecessary overfilling of packages can be reduced and brought to an acceptable level.

This case study shows that the model developed in this study can help manufacturers to get a quantitative output on the financial risks involved with their actual production processes and by combination of these risks with unnecessary inputs are able to quantify the potential of monetary savings. As the regulation of pre-packaged goods is unified throughout the European Union, the model can also be applied in many other countries throughout Europe. Due to its generic characteristics, the presented model can be transferred to other pre-packaged goods (food and non-food) and can hence have fruitful implications to other industries beyond the choclate production. Therefore, a subject for further reseach is the validation of the model and the determination of potential savings in other categories. In addition, the model could be implemented in the control module of modern filling technology so that real-time management of filling quantities on the shop floor would be enabled.

Returning to the initial motivation for this study a suitable alternative to downsizing has been introduced that allows manufacturers to save on inputs while on the other hand avoid the expected negative effects regarding their reputation and regarding fines.

References

Adams, A.; Di Benedetto, C.A.; Chandran, R. (1991): Can you reduce your package size without damaging sales? In: Long Range Planning, 24. (1991), No. 4, pp. 86-96.

AG Mess- und Eichwesen (2013): Kommentierte Bundesübersicht über Füllmengenkontrollen von Fertigpackungen für den Zeitraum 01.01.2012 – 31.12.2012. (https://www.lbme.nrw.de/download/fni_eichstatistiken-statistik_ueber_fuellmengenkontrollen_140606.pdf). Accessed on 10.12.2019.

AG Mess- und Eichwesen (2014): Kommentierte Bundesübersicht über Füllmengenkontrollen von Fertigpackungen für den Zeitraum 01.01.2013 – 31.12.2013. (https://www.lbme.nrw.de/download/Statistik_Fertigpackungen_2013.pdf). Accessed on 10.12.2019.

Al-Sultan, K. S.; Pulak, M. F. S. (2010): Process improvement by variance reduction for a single filling operation with rectifying inspection. In: Production Planning & Control, 8. (2010), No. 5, pp. 431-436.

Chen, C. H. (2004): Determining the optimum process mean based on asymmetric quality loss function and rectifying inspection plan. In: Proceedings. IEEE 2004 International Engineering Management Conference : innovation and entrepreneurship for sustainable development, 18-21 October 2004, Pan Pacific Hotel, Singapore. 2004 IEEE International Engineering Management Conference, Singapore, 18-21 Oct. 2004. IEEE Engineering Management Society; IEE Management Professional Network; IEEE International Engineering Management Conference (eds.). New York, N.Y: IEEE, pp. 1080-1084.

Chen, C.-H.; Lai, M.-T. (2007): Determining the optimum process mean based on quadratic quality loss function and rectifying inspection plan. In: European Journal of Operational Research, 182. (2007), No. 2, pp. 755-763.

Darwish, M. A.; Abdulmalek, F.; Alkhedher, M. (2013): Optimal selection of process mean for a stochastic inventory model. In: European Journal of Operational Research, 226. (2013), No. 3, pp. 481-490.

Ernährungsumschau (2008): Hohe Beanstandungsquoten bei Fertigpackungen. In: Ernährungsumschau (17.11.2008) (https://www.ernaehrungs-umschau.de/news/17-11-2008-hohe-beanstandungsquoten-bei-fertigpackungen/367050/). Accessed on 10.12.2019.

EU (ed.) (2007): Directive 2007/45/EC Of the European Parliament and of the Council of 5 September 2007 laying down rules on nominal quantities for prepacked products, repealing Council Directives 75/106/EEC and 80/232/EEC, and amending Council Directive 76/211/EEC.

FertigPackV (ed.) (1981) [Verordnung über Fertigpackungen (Fertigpackungsverordnung)] of 18.12.1981. (1981). (https://www.gesetze-im-internet.de/fertigpackv_1981/). Accessed on 10.12.2019.

Fincke, A.; Krauss, P. (1967): Füllmengenstreuungen bei Fertigpackungen mit Lebensmitteln. In: Fette, Seifen, Anstrichmittel, 69. (1967), No. 11, pp. 849-854.

Kahneman, D.; Knetsch, J. L.; Thaler, R. H. (1986): Fairness as a Constraint on Profit Seeking: Entitlements in the Market. In: American Economic Review, 76. (1986), No. 4, pp. 728-741.

Leibinger, T. (2017): Downsizing bei Konsumgütern. Wiesbaden : Springer Fachmedien Wiesbaden.

MessEG (ed.) (2013) [Gesetz über das Inverkehrbringen und die Bereitstellung von Messgeräten auf dem Markt, ihre Verwendung und Eichung sowie über Fertigpackungen] of 2013. (2013) (https://www.gesetze-im-internet.de/messeg/BJNR272300013.html). Accessed on 10.12.2019.

Tahera, K.; Chan, W. M.; Ibrahim, R. N. (2008): Joint determination of process mean and production run. A review. In: The International Journal of Advanced Manufacturing Technology, 39. (2008), No. 3-4, pp. 388-400.

Authors

Prof. Dr. Matthias **Lütke Entrup** is professor of Operations Management and Controlling at the International School of Management in Dortmund. He has previously worked 12 years in the consumer goods and operations practices of the consultancy A.T. Kearney and as CFO of the German fruit juice group Valensina. His research interests focuses on supply chain management and production planning topics in consumer goods industries.

Edwin **Tiedge-Arnold** is working as a data analyst for Höveler Holzmann Consulting, a consultancy for procurement and supply chain management in Düsseldorf. Previously he studied business mathematics in Wuppertal. He holds an MSc degree in mathematics with focus on operations research.

Prof. Dr. Jens K. **Perret** is a professor for Economics and Statistics at the International School of Management in Cologne. Previously, he has worked for nine years at the European Institute for International Economic Relations at the University of Wuppertal. His research interests focus mainly on knowledge economics and structural change.