Delivering best consumer experience
Implementation of basic statistics in the world of coffee machines to support best in-cup quality and 0 defect objective

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Abstract
Coffee machines manufacturing has been growing significantly in past years at Nespresso reaching a volume of more than 8 million appliances manufactured in 2015 (including milk frothers). To support Nestlé ambition of 0 defect on coffee machines (industry standard is between 3 and 7% return rate) and in cup quality consistency, intensive use of statistics has become a must. We propose to show the implementation of statistics through 4 practical successful examples:

- Design Of Experiments performed on Aeroccino milk frother to solve the issue linked with burnt milk and to ensure successful worldwide launch
- Design Of Experiments performed on Inissia coffee machine to reduce the number of complaints linked with noise
- Tolerancing properly process/test limits to avoid double distributions which have for consequence in cup volume being out of spec for U coffee machine
- “Machine-Capsule” System qualification and validation to ensure in cup consistency (coffee extraction and sensory aspects)

Keywords: Statistics, Coffee Machine, Milk frother, In Cup, DOE, Sample size, Critical parameter, Confirmation run, validation, protocol, statistical approach, consistency.

1. Introduction

Coffee machines manufacturing (B2C –Business to Consumers-, B2B –Business to Business-, airplanes…) has been growing significantly in past years at Nespresso reaching important volumes (more than 8 million in 2015 including milk frothers). To support Nestlé ambition of 0 defect on coffee machines and in cup quality consistency, use of statistics has become a must.

2. Examples

Statistics are progressively being implemented within Nespresso especially on coffee machines and milk frothers manufacturing. This is being done by applying tools and methodology but also by modifying the mindset using more and more risk based approach. Following examples highlight some practical application of basic statistics.

2.1 Aeroccino4 burnt milk

2.1.1 Background

Production of new milk frother Aeroccino4 started a few months ago to support a worldwide launch during the spring of 2016.

2.1.2 Issue

12% Milk burnt issue was escalated by Nespresso markets and observed during routine life cycle tests during production ramp-up in 2015.

2.1.3 Statistical method: DOE

The Design Of Experiments method has been selected to identify the key problem factors (burnt milk) and to try to optimize them in order to eradicate this issue and provide best in class products to Nespresso customers (without burnt milk). First action was to fix the milk type as it was clear that the type of milk had an important influence (quantity of fat, temperature, etc…). Milk was therefore selected with 2% fat and at a temperature of 6 degrees Celsius.
Brainstorm between Engineering, Quality and the milk frother manufacturer then helped determining a list of process influencers. Following parameters were selected: Heater plate resistance, coating, electrical voltage, Temperature sensor (NTC), whisk type.
A DOE was prepared with these parameters as well as the identification of the extreme values and the selection of representative samples. DOE was then run with 2^5 trials repeated 4 times and output (milk burnt) was assessed.
Main influencer on burnt milk was identified to be the resistance of the heater. Interactions of heater resistance and voltage as well as heater resistance and Temperature sensor were found to be the most significative. Heater resistance specification was adjusted and properly controlled at supplier level. Temperature sensor (NTC) tolerance and therefore variability was reduced from +/- 2% down to +/- 1%. Whisk roundness tolerance was also reduced.

Confirmation run with the above conditions was executed with 188 samples.

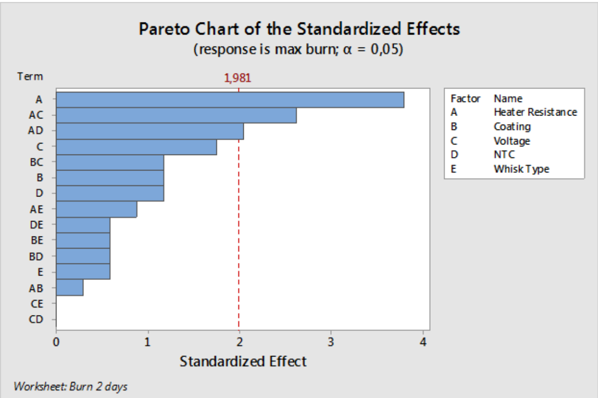

Fig 1: Pareto Chart of the standardized effects

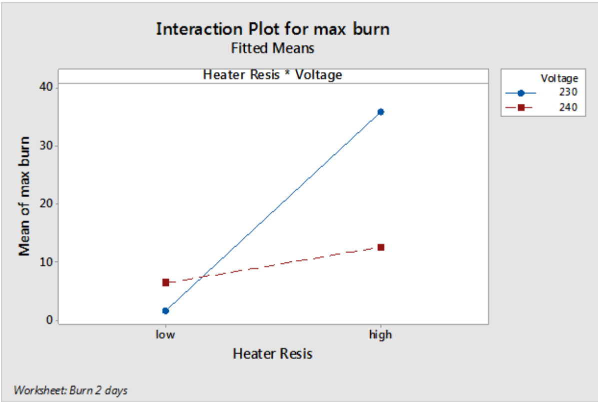

Fig 2: Interaction Plot for Max burn

2.1.4 Results

Confirmation run on 188 samples demonstrated that occurrence of burnt milk was reduced by a factor 100 down to 0.12%. On worst case scenario with reconstituted milk (Hong Kong), occurrence was reduced from 32% down to 1.2%. User Manual was also updated to recommend the right type of milk and encourage proper cleaning, so as to further reduce the occurrences at consumer. Finally, laboratory test standards were updated for future milk burning tests.

2.2 Noisy Inissia

2.2.1 Background

Inissia is Nespresso best seller for B2C machines within Nespresso. Worldwide Launch was performed end 2013 first in Italy, Spain and Portugal (soft launch) and a few months after in the rest of the world.

2.2.2 Issue

Noisy machines were detected after a quantity of 50-100 coffee preparation during routine life cycle tests performed in parallel of the daily production a few months after official production start.

Root cause was identified to be the delamination of the anti-back-flow check valve (specific component which prevents the liquid coffee to be back in the fluidic system during extraction).

This check valve is a bimaterial component and delamination was observed between both materials creating the unpleasant noise during coffee extraction.

2.2.3 Statistical method: DOE

The Design Of Experiments method has been selected to optimize the process parameters of injection molding process at check valve supplier level. Critical parameters were identified to be the injection temperature and the cavity of the mould. This injection mould has effectively 16 cavities and the cavities have been identified as key influencers for the quality of the injection; because temperature may vary between the cavities.

Therefore, a DOE was prepared with 1 parameter (the injection temperature), and cavities were used to monitor this parameter. Preliminary, the DOE was performed with 8 machines. The output (Life cycle duration before noise increase) was assessed at coffee machine level. Differences were clearly observed between the 2 selected temperatures (265 and 275 degrees) but these differences were not significant.

The test power was quite low, so that the result was just informative. Nevertheless, a confirmation run was performed with 32 machines on the highest temperature setting and machines were successfully tested during life cycle tests; reaching an average of 3300 cycles before noise increases a bit.

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Two-Sample T-Test and CI: Nb Cycles;
Temp Injection
Two-sample T for Nb Cycles
Temp
Injection  N  Mean  StDev  SE Mean
265        4  2500    283      141
275        4  3575   1121      560
Difference = μ (265) - μ (275)
Estimate for difference:  -1075
95% CI for difference:  (-2914; 764)
T-Test of difference = 0 (vs ≠): T-
Value = -1,86
P-Value = 0,160  DF = 3
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Fig 3: T test results

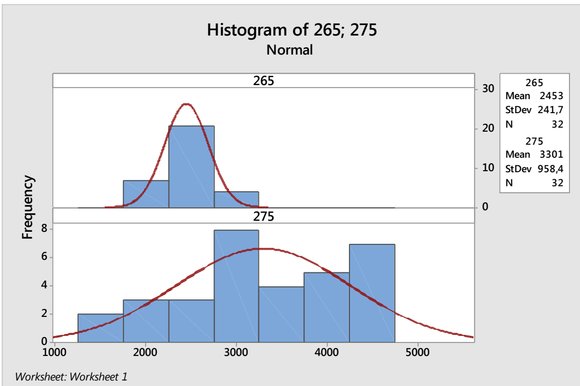

Fig 4: Histogram of injection temperature and number of cycles

2.2.4 Results

Consumer complaints for noise were drastically reduced (by more than a factor 10) on Inissia machines produced from March 2014 after the introduction of the check valve with an optimized injection molding process (higher injection temperature).

2.3 U in cup volume

2.3.1 Background

Innovative U machine was launched worldwide end of 2012. Main innovations were:

- The motorized brewing unit allowing the closing of this brewing unit through the move of a simple slider.
- The drop stop function allowing no more drops out of the coffee outlet at the moment of the capsule ejection

2.3.2 Issue

In Cup volume (25ml for ristretto, 40 ml for espresso, 110ml for lungo) was identified as out of spec during the final test within machine manufacturer for a high number of coffee machines.

2.3.3 Statistical method: Statistical distributions & Tolerancing

Root cause investigations helped to identify 2 distributions within the "in cup volume" test with a 2nd marginal distribution not centered on the targeted 25ml (ristretto), 40 ml (expresso), 110 ml (lungo) volume. Double distribution was also observed at the pressure test. This test verifies the tightness of the brewing unit putting this brewing unit under a certain pressure for a certain amount of time. A 2nd marginal distribution was observed corresponding to a leakage in the brewing unit. Root cause was confirmed by performing in cup tests on machines coming from the marginal distribution at pressure test. Insufficient coffee quantity was measured. Upper test limit was then modified with respect to the main Gaussian applying a Ppk of 1.33 on the upper side to make sure marginal machines are rejected on the manufacturing line. Manufacturer has been working to understand root cause of leakages and implement corrective actions in order to reduce reject rate at pressure test. All other distributions of machine characteristics coming from production tests were checked and no other marginal distribution was observed.

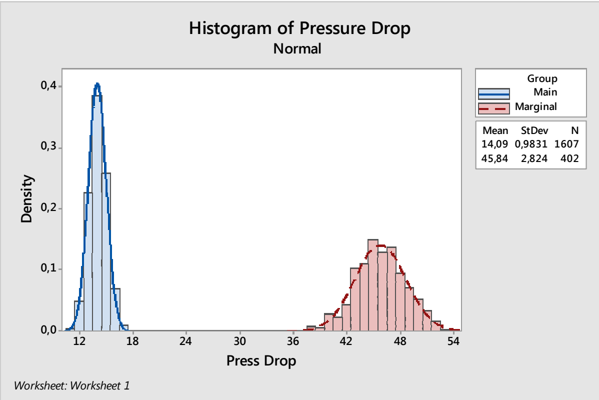

Fig 5: Double distributions at pressure test

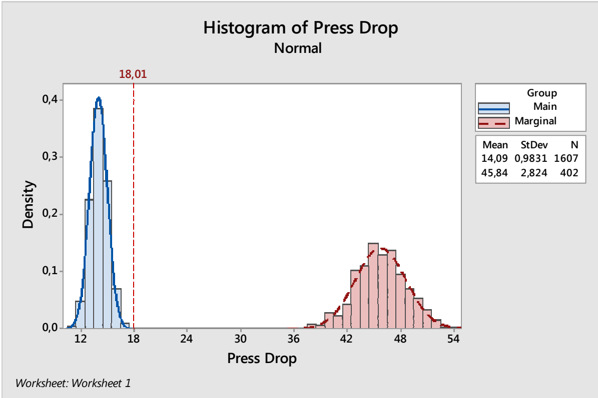

Fig 6: Tolerancing with a Ppk of 1.33

2.3.4 Results

Coffee quantity in cup was back within specifications for U machine. This helped to improve the quality of machines coming out of the manufacturing line and therefore helped also to reduce then related number of complaints. Production release checklist has been updated for any new machine developed to make sure this case never happens again for any variable characteristic.

2.4 System (Machine/Capsule) interaction

2.4.1 Background

No statistical approach was existing to perform the validation of the interaction between coffee capsule and coffee machine.

2.4.2 Issue

For each new machine or new grand cru validation, it was almost impossible or at least very complicated to understand the root causes of some observed deviations on the in cup parameters (temperature, flowtime, etc.).

2.4.3 Statistical method

First step was to train on statistics all people working in the machines and coffee laboratory in order to make sure everyone had at least a basic understanding of the methods used. This training was performed with the help of Minitab. All test methods to measure in cup quality (temperature, flow time, pressure, etc.) were then reviewed and updated to have a consistent and statistically relevant number of samples. As an example, it helped to reduce the number of extractions by machines but to increase the number of machines tested. Then, a complete statistical protocol, together with Minitab, was created to include different elements such as the dummy capsule, the reference coffee, the reference machine. First action was to validate properly the reference machines from the laboratory with the validated dummy capsule. It helped to validate the reference coffee used in the lab. Each reference coffee batch is now validated separately with the creation of golden samples. Each qualification phase (Reference machine, reference coffee, dummy capsule, new coffee, new machine) was described using a statistical decision tree based on normality study, capabilities, ANOVA…). A user guide was created with Minitab to help the technicians and engineers with statistical validation.

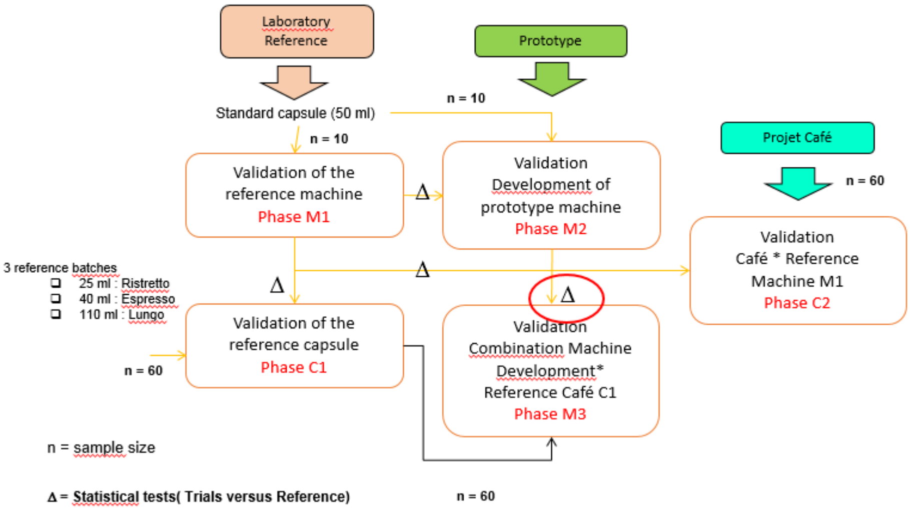

Fig 7: Statistical validation plan

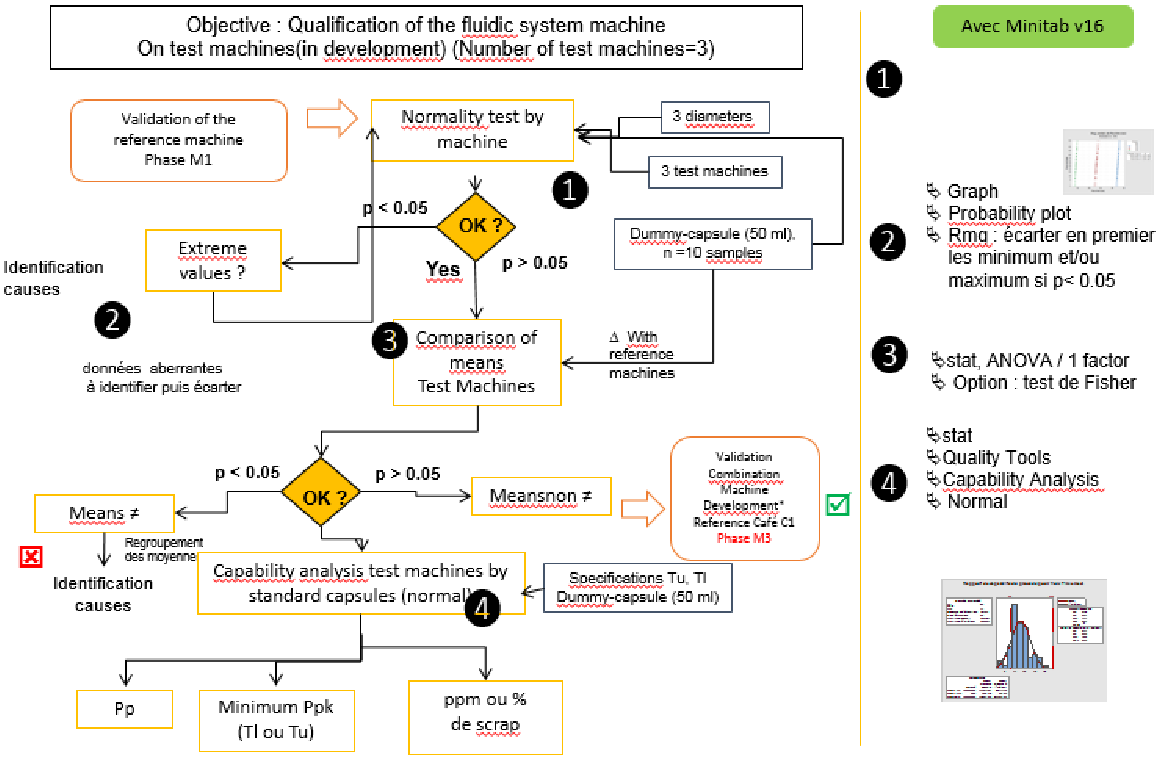

Fig 8: Specific process using statistical data analysis

2.4.4 Results

With a robust statistical approach, Nespresso is now able to validate properly any new developed coffee or any new developed machine.

This helps on multiple aspects:

- Ensuring in cup consistency between all the new machine models and all new grand crus launched
- Reducing the consumer complaints linked with in cup parameters (temperature, flow stops, etc.)
- Reducing time to market by reduction of sample size therefore test duration

3. Conclusion

Implementing statistics even basics of statistics is a long, progressive but mandatory journey in order to reach quality excellence.

The 4 examples listed in this document sound very basic but they strongly supported a real change in the quality and reliability of coffee machines within Nespresso.

Even if Nespresso is moving towards soft launches to reduce the risks of epidemic failure, when more than 500 000 machines are produced in a row for a worldwide launch, this is obvious that statistics needs to be leveraged to minimize the risks of such epidemic failure with the associated consequences.

Nespresso is now able to place on the market home appliances and professional machines with unequal low level of complaints or field interventions.

In order to keep moving towards 0 defect objectives, use of more advanced statistical practices needs to be further expanded especially in Design & Development phases but an important step has been already made with the basics.

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