Quality assessment of temperature measurements in incoming inspection of raw meat

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Abstract. A system based on the HACCP principles represents an effective tool for poultry processing. This system provides risk identification and corrective actions for it reducing. A low level of metrological assurance of CCP effects on risk identity because it depends on accuracy of measurement information. MSA method for measurement assessment of CCP in poultry production is recommended. The metrological analysis of CCP for technology process is developed. The researches of temperature of cooled poultry meat is traced in real-time production. At the first step with the use of control diagrams the stable measurement process was established. Second step showed the absolute and relative meanings for deviation in measurement process. At the third stage the assessment of measurement deviation was leaded. At the final stage over result grading the top ways of reducing measurement deviation were estimated. The analysis showed that measurement process should be improved. Changes the properties of meat samples is the major during temperature measurement. The second place is for measurement repeatability. The measurement method is important, that’s why for reducing the measurement deviation it is recommended to change the method or choose another measuring instrument. The role of mechanic was not recognized. Proposed assessment approach for measurement process of CCP based on HACCP principles in order to identify risks within the food safety control and to minimize technique regulation procedure.

1. Introduction

Quality control plays an important role in poultry processing. Monitoring of parameters based on quality control and statistical methods [1]. With the use of these methods it is possible to identify production risk and to reduce it [2, 3]. The HACCP procedure is an effective tool for wide application. The main advantage of HACCP is the CCP determination [4]. To determine the controlled parameter is essential for quality control and monitoring system. Monitoring includes requirements, methods and measurement tools to provide CCP identifying. Methods and measuring instruments have to provide involved accuracy of results, and the priority is the metrological achievement of CCPs [5, 6].

This task is difficult and multistage, and may be solved within the production process [7, 8]. Among this, to sum up the requirements for measurement tools and methods. Next, the measurement process modeling is started in collaboration with these requirements. The accuracy of measurement process – is the main aim for technology. The «six Sigma» method is essential here. The last point is the analysis of metrological supervision for CCP. The analysis identifies quality risks and estimates the level of metrological supervision. These results may improve the monitoring system.
For efficiency analysis of metrological supervision, it is important to develop the algorithm, that can estimate the measurement process acceptability in real-time production, in which, basically, MSA method is used.

2. Materials and methods

In accordance to HACCP principles the worksheet for poultry meat processing is created. For metrological CCP assurance for poultry production process the list of measurement instruments is composed (table 1).

Table 1 shows the several measurement instruments, like: digital thermometer «Zamer-1» (TS 4215-002-13245171); edgewise meter of temperature and humidity ITR 2605 (TS 4227-004-34913634).

The proposed methods are used for CCP1 identification – variations of meat temperature.

The Incoming material control is the most significant requirement for food safety. Just at this step the question of further processing is discussed.

The experiment for stable measurement process assessment was constructed. The control diagram analysis didn’t cause any variability deviations. Therefore, the measurement process is in stable conditions and it is possible to begin the acceptability assessment.

Table 1. The HACCP worksheet.

| Operation                        | CCP number | Controlled parameter       | Criterion limit       | Corrective action                                                      | Measurement instrument |
|----------------------------------|------------|---------------------------|-----------------------|------------------------------------------------------------------------|------------------------|
| Feed preparation                 | CCP1       | Meat temperature:         |                       | Improper feed isolation                                                | «Zamer-1»              |
|                                  |            | cooled                    | (0 ± 1)°C             |                                                                        |                        |
|                                  |            | frozen                    | (2 ± 2)°C             |                                                                        |                        |
| Feed defrostation                | CCP2       | Room temperature          | (5 ± 1)°C             | Cooling equipment check-out                                            | ITR 2605               |
|                                  |            | Meat temperature          | (2 ± 2)°C             |                                                                        | ITR 2605               |
| Anatomical cutting of meat       | CCP3       | Meat temperature          | (2 ± 2)°C             | When temperature is more than 5°C, raw material will be placed in cooling camera and then will be processed | «Zamer-1»              |
| Frosting                         | CCP4       | Product temperature       | No less than -12°C    | To inspect the cooling equipment operation in order to eliminate temperature abuse | «Zamer-1»              |

For deviation of measurement process for poultry meat temperature the digital thermometer «Zamer-1» (error ±0.5°C), digital standard thermometer «TCA-0.005/MA» (error ±0.002°C) were used. The measurement was carried out 10 times. Bias voltage and its relative value on the formulas (1) and (2).

\[
B = \bar{X} - X_t; \tag{1}
\]

\[
\%B = (|B| / T) \cdot 100, \tag{2}
\]

where \(\bar{X}\) – mead value of measuring results for evaluated measuring instrument; \(X_t\) – true value (standard instrument); \(T\) – tolerance for controlled parameter.

The results are established in the table 2.

There were five samples of poultry meat for determination the repeatability and reproducibility measuring meanings. The operators measured \(M=3\), temperature was measured by three operators \(Q=3\). The set of points is obtained. The table 3 shows the results.
Table 2. Check sheet for calculation the measurement process deviation for poultry meat temperature.

| Measurement | Temperature measurement of meat, °C |  |
|-------------|-----------------------------------|---|
|             | cooled                            | frozen |
| True value  | 0.257                             | 2.847  |
| Effort      | 1.0                               | 2.5    |
|             | 0.5                               | 2.5    |
|             | 0.5                               | 3.0    |
|             | 0.5                               | 3.0    |
|             | 0.0                               | 3.0    |
|             | 0.5                               | 2.5    |
|             | 0.5                               | 2.5    |
|             | 0.5                               | 2.5    |
|             | 0.5                               | 2.5    |
|             | 0.0                               | 2.5    |

Variance estimate $S_e^2$ of measuring instrument:

$$S_e^2 = \frac{1}{MN(Q-1)} \sum_{i=1}^{N} \sum_{j=1}^{M} \sum_{k=1}^{Q} (X_{ijk} - \overline{X})^2,$$

(3)

where $NM(Q-1)$ – variance.

Variance estimate $S_o^2$ for the human (operator):

$$S_o^2 = \frac{NQ}{M-1} \sum_{j=1}^{M} \left( \overline{X_{j.}} - \overline{X_{..}} \right)^2,$$

(4)

where $M-1$ – variance.

Table 3. The set of points for repeatability and reproducibility.

| Measurements, $Q$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|------------------|---|---|---|---|---|---|---|---|---|---|
| For cooled poultry meat | 0.5 | 0.0 | 0.5 | 0.5 | 0.0 | 0.5 | 0.5 | 0.0 | 0.5 | 0.5 |
| 1 | 2 | 0.0 | 0.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.0 |
| 3 | 1 | 0.5 | 0.5 | 0.0 | 0.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.0 |
| 2 | 2 | 0.5 | 0.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 3 | 1 | 0.0 | 0.0 | 0.5 | 0.5 | 0.0 | 0.5 | 0.5 | 0.5 | 0.0 |
| 2 | 2 | 0.5 | 0.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 3 | 1 | 0.5 | 0.5 | 0.0 | 0.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.0 |

| For frozen poultry meat | 2.5 | 2.5 | 3.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
|-------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1 | 2 | 3.0 | 3.0 | 3.0 | 2.5 | 2.5 | 3.0 | 2.5 | 2.5 | 3.0 |
| 3 | 2 | 2.5 | 3.0 | 2.5 | 3.0 | 3.0 | 2.5 | 3.0 | 2.5 | 3.0 |
| 1 | 2 | 3.0 | 3.0 | 3.0 | 2.5 | 2.5 | 3.0 | 2.5 | 2.5 | 3.0 |
| 3 | 2 | 2.5 | 2.5 | 2.5 | 3.0 | 3.0 | 2.5 | 3.0 | 2.5 | 3.0 |
| 1 | 2 | 3.0 | 3.0 | 3.0 | 2.5 | 2.5 | 3.0 | 2.5 | 2.5 | 3.0 |
| 3 | 2 | 2.5 | 2.5 | 2.5 | 3.0 | 3.0 | 2.5 | 3.0 | 2.5 | 3.0 |
Variance estimate $S_p^2$ for poultry meat samples:

$$S_p^2 = \frac{MQ}{N-1} \sum_{i=1}^{N} \left( \bar{X}_{(i)} - \bar{X} \right)^2,$$

where $N-1$ – variance.

Variance estimate $S_{op}^2$ for operator and samples interaction:

$$S_{op}^2 = \frac{Q}{(N-1)(M-1)} \sum_{i=1}^{N} \sum_{j=1}^{M} \left( \bar{X}_{ij} - \bar{X}_{(i)} - \bar{X}_{(j)} + \bar{X} \right)^2,$$

where $(N-1)(M-1)$ – variance.

The repeatability of measuring results $EV$:

$$EV = K_a \cdot S_p.$$

The reproducibility $AV$ of measuring results:

$$AV = K_o \cdot S_o.$$

thus, the variability $PV$ of poultry meat samples is:

$$PV = K_o \cdot S_o.$$

Should calculate only if operator and samples interaction is signified.

The repeatability and reproducibility $R&R$ of measuring results on the formula of probabilistic composition:

$$R&R = \sqrt{EV^2 + AV^2}.$$

Total variability $TV$ for measuring process:

$$TV = \sqrt{R&R^2 + PV^2}.$$

The acceptability of the measuring process, which is used for controlled parameter and tolerance suitability is determined and based on relative repeatability and reproducibility meanings:

$$R&R_T = \frac{R&R}{TV} 100\%.$$

For complex analysis the relative meanings of variability parts should be calculated - repeatability, reproducibility, sample variation, operator and sample interaction are established:

$$EV_{TV} = \frac{EV}{TV} 100\%;$$

$$AV_{TV} = \frac{AV}{TV} 100\%;$$

$$PV_{TV} = \frac{PV}{TV} 100\%.$$

| 2  | 2.5 | 3.0 | 2.5 | 3.0 | 3.0 | 2.5 | 3.0 | 3.0 | 3.0 |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 3  | 2.5 | 3.0 | 3.0 | 2.5 | 3.0 | 2.5 | 2.5 | 2.5 | 2.5 |
Thus, the initial data and theoretical relations were estimated for calculation the researched parameters.

3. Results and discussion
The results of measuring process deviation and its relative meanings are defined by the formulas (1) and (2).

Table 4. Accounting results of measurement process deviation for poultry meat temperature

| Variability parts                  | Items for poultry meat |
|-----------------------------------|------------------------|
|                                   | cooled | frozen |
| Tolerance, °C                     | 2      | 4      |
| Average values, °C                | 0.3    | 2.65   |
| Accuracy error B, °C              | +0.043 | -0.197 |
| Relative shift B, %               | 2.15   | 4.925  |

If relative meaning for cooled and frozen meat is less than 10%, the measuring process deviation for poultry meat temperature will be acceptable. The variance estimate calculation as a component of measuring process deviation is shown on the formulas (3) – (6). In the table 5 there are meanings of mean square deviation.

Table 5. Mean square deviation results for poultry meat temperature

| Variability parts                             | Mean square deviation characteristic for meat temperature |
|-----------------------------------------------|---------------------------------------------------------|
|                                               | cooled | frozen |
| Repeatability, °C                             | 0.269  | 0.269  |
| Reproducibility, °C                           | 0.053  | 0.091  |
| Variability of samples parameters, °C         | 0.274  | 0.251  |
| Operator and sample interaction, °C           | 0.257  | 0.274  |

Formulas (8), (9) and (11) established the meanings for measuring process. At the significance level \( \alpha = 0.99 \), \( K_n = 5.15 \).

Table 6. Accounting results of variability parts and measuring results of poultry meat temperature

| Variability parts                             | Variability parts of temperature results for poultry meat |
|-----------------------------------------------|---------------------------------------------------------|
|                                               | cooled | frozen |
| Repeatability \( EV \), °C                   | 1.38   | 1.38   |
| Reproducibility \( AV \), °C                 | 0.27   | 0.47   |
| Variability of samples parameters \( PV \), °C| 1.41   | 1.29   |

With the use of meanings from the table 1 and formulas (10), (11) and (12) the repeatability and reproducibility, total variability and relative meanings of repeatability and reproducibility may be found. The obtained results are presented in the table below (table 7).

Table 7. Accounting results of acceptability of measurement process for poultry meat temperature

| Variability parts                          | Variability parts of temperature results for poultry meat |
|--------------------------------------------|---------------------------------------------------------|
|                                            | cooled | frozen |
| The repeatability and reproducibility \( R&R \), °C | 1.41   | 1.46   |
| Total process variation \( TV \), °C        | 1.99   | 1.95   |
Relative repeatability and reproducibility of measuring process $R&R_T$, %

70.5 36.5

For total analysis with the use of formulas (13), (14) and (15) the repeatability, reproducibility and samples variation may be determined. The insights are obtained from experiments are established in the table 8. These meanings show that measuring process have to be improved, due to the fact that the Relative repeatability and reproducibility of measuring process is higher than the standard value ($R&R_T > 30\%$).

Table 8. Accounting results of relative variability parts and measuring results of poultry meat temperature

| Variability parts | Variability parts of temperature results for poultry meat |
|-------------------|----------------------------------------------------------|
|                   | cooled | frozen |
| Relative repeatability of results $E_{TV}$, % | 69.3 | 70.9 |
| Relative variability on human $A_{TV}$, % | 13.6 | 24.1 |
| Relative variability on sample parameters $P_{TV}$, % | 70.8 | 66.2 |

The main role of total measuring process deviation of poultry meat temperature plays the sample variability in cool and frozen conditions. The re-engineering of cooling technology, changing storing parameters up to the anatomical cutting and maintaining these points during the transportation can be effected according to the variability parts.

Next through the measuring process is the repeatability of results. It is important to maintain the measuring method or choose the accurate measuring instrument to decrease the measuring process deviation level. The proportion of operator should be regarded as insignificant.

4. Conclusions
Metrological supervision of food production process – is the main criteria for safety and quality control. The suggested method of measuring process acceptability provides the factors detection which effect on measuring deviation.

For cooled and frozen poultry production process the measuring instrument for temperature content should be changed. The incoming material control have to be provided. Over the meat freezing the characteristics for stable process should be increased. The storing parameters should be controlled.

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