

SYSTEM FOR RECORDING THE ANALYSIS RESULTS AS PART OF THE QUALITY CONTROL PLANES IN A STARCH FACTORY

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Abstract

The paper aims to present the way in which a recording data system can be created using only programming in the EXCEL software, proposed as an efficient alternative to other expensive and complicated software programmes. A quality plan of a starch factory was taken as reference and a recording data system was issued starting from the results usually obtained at the analyses performed to ensure and follow the quality of the products. Each production step is controlled and for each product several parameters are identified using different analysis methods. The results are recorded and various functions available in EXCEL are used in order to facilitate the data interpretation, as well as to reduce at minimum the human errors. Instead of the paper recording results, we create easy to use EXCEL files in which the important data are marked, to facilitate the control of the production process and validate the quality and safety of the finished products.

Key words: quality control, data recording system, starch.

INTRODUCTION

Quality is defined by ISO 9000 as being the “degree to which a set of inherent characteristics fulfils requirement” and it is one of the most complex notions, which includes the product capacity to satisfy the requirements and, also, economical aspects related to its production and uses (Chira, 2010). The quality control plans are issued in order to ensure that the products obtained during a technological process correspond to their technical specifications.

The production process used in a starch factory is based on the wet-milling, being described in the literature as a big scale complicated process, aiming to separate the chemical components from the corn kernels (Jackson and Shandera, 1995). The principal production steps include:

- Steeping corn kernels
- Milling and germs separation
- Hulls separation from milled corn
- Gluten separation
- Wash and dehydrating the starch slurry
- Starch drying and packaging

The most important steps are steeping and gluten separation (Malumba et al., 2009).

In a starch plant the quality control plan should include production process steps, samples to be analyzed, parameter check, acceptance range, analysis method, frequency and the methodology of recording the results.

In order to be able to control a production process, assure the quality of the final product in accordance to the product technical data sheet, the analyses results must be constantly recorded and reported in a manner which allows for an easy interpretation.

Although, to manage the records from the laboratory special software already exists, such as Laboratory Information Management Systems (Paszko and Turner, 2002; Helsens et al., 2010; Stephan et al., 2010) or Electronic Laboratory Notebooks (Dessy, 2002; Rubacha et al., 2011), they are expensive and not custom-made. It is always a challenge for any company to be efficient and to save money (Brown, 2001), thus, an in-house developed record system may help doing that. An alternative to some commercial softwares is the use of Excel, which was used before as a laboratory data management tool, as described in several research papers for applications in HPLC (Rubin et al., 2010), for

electrophysiological data (Brown, 2006) or even for complex testing (Wahlsten, 2011). All these papers aimed to offer an alternative to the expensive software created for manage the data in laboratories.

This paper shows an alternative laboratory results recording system, by using connected Excel files, which allow for safe and rapid control of the production process, in order to assure the quality of the final products.

MATERIALS AND METHODS

In order to create an optimal recording system, all the types of analytical results were gathered and several worksheets were designed in Excel to accurately describe the recordings usually kept on paper files as part of the quality control plan. The excel files were designed to be used more easily than the paper records, allowing for the automate calculations and straightforward interpretation of results. For the automatic calculations Excel available formulas and functions were used for programming, while for the interpretation, conditional formatting facility was used to provide results in several colours and fonts, to signal normal values or to emphasize cases when the allowed range is exceeded.

We took into account the monitoring frequency for each step and the way in which the recorded data (the analysis results) are to be further used. The working sheets were issued in a certain established order, to allow us to obtain reports of the average results per day, month and year. The abbreviations used in all the Excel files, in alphabetical order, are the following:

- A.N.=native starch
- ARM=aerometer
- Be=Baumé
- BS=tank for preparing SO₂ solution
- C.=concentration
- CA=starch content
- CGF=corn gluten feed
- CGM=corn gluten meal
- Cnmt.=timing
- CSL=corn steep liquor
- Dep.=storage
- DESH. GLT.= gluten dehydration
- Evac.=evacuation
- F.G.=heavy phase
- G=fat

- G.I.=steeping grade
- G.I.G.=installation for concentrate the steeping solution
- G.P.= corn gluten
- Gz.=granularity smaller than 160 microns
- H=hours
- I.M.=before milling
- L.A.=starch slurry
- Ln=line no. n
- nH=sampling frequency at each n hours
- P=protein
- PMn(m)=average sample formed from first n samples taken to each m hours
- P.N.=black spots
- R.S.=washing ratio water/L.A.
- S.=solution
- S.A.G.=suspension of starch and gluten
- SEP.=separation
- SU=dry substance
- T.A.=starch cake
- T.G.=gluten cake
- T.I.=steeping time
- T=temperature
- TR= thermometer
- U=moisture

The entire industrial process was presented in a previous paper (Deciu and Antoce, 2014).

RESULTS AND DISCUSSIONS

The laboratory results record keeping is a system of several Excels files and worksheets. All the Excel files created for each product contain a sheet with working instructions and abbreviations, the sheets in which the analysis results are recorded and one sheet for monthly and annually average value reports. Each monitoring working sheet contains a table having in the headings all the information necessary to fulfil the quality control as follows: production step, sample submitted for analysis, type of analysis, method of analysis, analysis frequency and acceptance ranges for the results.

For the first production step, the steeping of the corn kernels, an Excel file was created to include the analysis results for each steeping tank, for each tank used to prepare SO₂ solution and for the by-product obtained after the concentration of the steeping solutions. An example for table headings is presented in

Table 1 and for monitoring recording in Figure 1.

Table 1. Information record for the Steeping Production Step as transposed from the Quality Control Plan

STEEPING TANK NO. 1						
Step	CORN STEEPING					G.I.G.
Sample	STEEPING SOLUTION / CORN					CSL
Analyze	SO ₂ (%)	SU(%)	T(°C)	T.L.(ore)	G.I.(%)	SU(%)
Limits	≤ 0.15	≤ 25	48-52	42 - 72	≥ 42	46-52
Method	IL-L-04	IL-L-07	TR	Cmmt.	IL-L-05	IL-L-07
Frequency	3H	3H	3H	I.M.	I.M.	3H EVAC./ 12H DEP.

In order to facilitate the visualisation of the analysis method used and to check the established reference values, we created for both cases a „hyperlink”, which leads and open the respective document stored on the server. In this way the human errors and the time necessary to check the data and the documents related to the quality control plan are reduced to a minimum level, because with just one click of a mouse the user is directed to the correct document.

Then, the system continues by identifying the optimal monitoring form for each production step, by taking into account the monitoring frequency and the way in which the data need to be later used. Even though the monitoring frequency is the same for almost all the analysis types and the data recording design is made in such a manner that should easily permit the calculation of an average after a given period of time, for the steeping step simple data recording way would not be helpful enough. Thus, because for the steeping process the average per day or per month is only useful for the process quality control, but not to monitor the evolution throughout the steeping cycle, it was chosen to centralize the analysis results for each steeping tank.

Each table in which the data should be recorded includes 8 rows and 72 columns. The first column indicates the information which should be recorded in each row. The fourth row has the values already set, from 1 to 72, representing the maximum period of time for corn steeping, in hours. Taking into account these values, at each 3 hours the analyst will

select the number of hours corresponding to the sampling time and then input the analysis results for each of the following parameters: sulphur dioxide concentration, dry substance, temperature and steeping grade.

The Excel sheet formatting used to highlight the values which are outside the reference range was done using the function „Conditional Formatting”. For each line type a specific rule is present: for all the cells which contain reference values, the formatting „Format all cells based on their values”, „Format Style: 2-Color Scale”, „Colour” is used, while for the cells which contain other values than the reference the formatting „Format only cells that contain”, „Format only cells with: Cell Value”, „Format” is applied.

As they are input, the values become differently coloured, as follows: the values which are out of the reference range will become red and bold on a white background, while the normal values will remained black, but positioned on cells with light orange background (Fig. 1). At the right end of each table with measured parameters of each tank, another small table is placed to include the concentration of the sulphur dioxide solution used in the process. This table (Figure 1 right side) includes the time, the sulphur dioxide concentration was measured and the tank from which was taken. The analyst should record: name, date, sampling time and the value obtained for the concentration. After input, a good value for the solution concentration appears on a background coloured in green, showing that the SO₂ solution can be released in the steeping process. In case that the cell containing the concentration value does not appear coloured in green then, in the tank with an insufficiently concentrated solution more sulphur dioxide should be added and the analysis repeated. The new values are recorded in the table and when the concentration is signalled as being correct, the process of steeping is started. Figure 1 contains an example of a record for 2 steeping tanks, their measured parameters after 1, 4 and 7 h of steeping and the concentration of sulphur dioxide solutions used in the process.

Steeping Tank no. 1													
Analyst:	Name				...	Name				Analyst: Name			
Date:	14/15.01.2016				...	17.01.2016				Date: 17.01.2016			
Time:		01:00			04:00			07:00			Time:	SO ₂ (%)	
Duration (H)	1	2	3	...	53	54	55	56	...	72	Tank	1	2
SO ₂ (%)		0,003		...	0,116				...		07:00	0,1	
SU(%)		17,8		...	4,3				...		08:00		0,09
T(°C)		24		...	48				...		12:00	0,21	
G.I.(%)				...				42,3	...		13:00		0,19
Steeping Tank no. 2													
Value in range													
Analyst:	Name				...	Name				Analyst: Name			
Date:	14/15.01.2016				...	17.01.2016				Date: 17.01.2016			
Time:			01:00		04:00			07:00			ORA	SO ₂ (%)	
Duration (H)	1	2	3	...	54	55	56	57	...	72	Tank	1	2
SO ₂ (%)			0,005	...	0,119				...		07:00	0,1	
SU(%)			18,3	...	4,7				...		08:00		0,09
T(°C)			26	...	48				...		12:00	0,21	
G.I.(%)				...				41,9	...		13:00		0,19
Value out of range													
Value to be released													

Figure 1. Example of a record for 2 Steeping Tanks

It can be observed that the cells in which normal values are recorded are coloured, while the values which do not fall within the established limits are marked with bold font and red colour. In this way the results obtained from analyses can be rapidly observed and easier interpreted. In order to keep unaltered the formatting in a table, some simple rules should be obeyed when filling the result boxes. Among those rules it can be mentioned:

- No text should be recorded in the numeric cells, because the text format will affect the application of formula and the already set conditional formatting, which depends on numbers magnitude;
- The cells in which values are calculated based on should be protected with passwords during programming.

The cells protection is made using the function „Protect Sheet”, which allow to decide which actions are permitted for the users. The administrator establishes the rules and then sets a password for rule change. In the Excel file created to record parameters during the steeping step, a formula is used only for dry substance calculation and monitoring in the CSL, being reported as the mean value of several measurements:

$$= \text{average}(\text{number1}; \text{number2}; \dots)$$

In case no values are yet recorded in the file, in order to avoid an error displaying when the computer attempts to calculate the average and leave empty the cell containing the formula, another “IF” function is used, as follows:
 $= \text{IF}(\text{SUM}(\text{number1}; \text{number2}; \dots) = 0, "", \text{AVERAGE}(\text{number1}; \text{number2}; \dots))$

For the following steps, the production process is proceeding toward the obtainment of one or more of the final products: corn germs, corn gluten feed, corn gluten meal and corn starch, which are stored in bulk or/and packed. For these products the samples for the quality control are taken at each 3 hours and average values are calculated at the end of each shift, in order to highlight the batch characteristics. As the package method leads to certain requirements the best way to record the products parameters are in separate EXCEL files, either for the bulk products or for the packed products. Taking into account that the main final product is the corn starch and the others are only by-products, the record files for starch are separated from the by-product files. In the figures below we present examples with a recorded parameter file for germs separation and extraction steps (fig. 2) and for gluten separation and starch refining (fig. 3), respectively. It can be observed that the values

for the limits and the analysis methods are underlined due to the fact that they are linked to the correspondent document on the server. Also there are some values in red font which shows

that they are out of range. Average values are calculated for each shift, after 12 hours and for each day, after 24 hours.

Step	DEGERMINATION					EXTRACTION															
Sample	Wet Germs		Dried Germs			Wet Fiber		CGF	Corn Gluten Feed						BUNKER CGF						
Analyze	U(%)	CA%/SU	Smell	Aspect	U (%)	U(%)	CA%/SU	U(%)	Smell	Aspect	U (%)	P (%)	CA%/SU								
Limits	≤ 55	≤ 8.0	conform	conform	≤ 6.0	≤ 65	≤ 17	≤ 13	conform	conform	≤ 13	≤ 17	≤ 8								
Method	PS09	IL-L-03	S.1	IL-L-23	PS09	PS09	IL-L-03	PS09	S.1	IL-L-23	PS09	PS.06	IL-L-03								
Frequency	3H	PM2(3)	3H	3H	3H	3H	3H	PM2(3)	3H	3H	3H	3H	PM2(3)								
Point	Presser		Drier			Arm 1	Arm 2	Presser	Drier	Fiber Mill						A	B	C	D		
07:00	54,0		0	1	1,0	65,2	65,2		13,1	1	1	10,5						X			
08:00			rancid smell						12,4	1	1							X			
09:00																		X			
10:00	55,2	7,9	1	1	2,5	65,2	65,3	15,2	11,3	1	1	9,6		15,2				X			
11:00																		X			
12:00											unmilled							X			
13:00	53,8		1	1	5,6	63,5	61,1		8,5	1	0	6,2						X			
14:00									11,2	1	1							X			
15:00																		X			
16:00	55,0		1	1	3,0	66,1	65,9		10,9	1	1	9,9							X		
17:00																			X		
18:00												16,9							X		
Shift 1	54,5	7,9	1	1	3,0	65,0	64,4	15,2	11,2	1	1	9,1	16,9	15,2							
19:00	54,4		1	1	12,4	67,9	67,2		12,1	1	1	10,9							X		
20:00					2,4														X		
21:00																			X		
22:00	53,1	8,3	1	1	4,1	64,9	65,3	15,7	11,9	1	1	10,6		15,7					X		
23:00																			X		
00:00																			X		
01:00	53,6		1	1	5,9	63,9	64,1		9,8	1	1	9,2							X		
02:00																			X		
03:00																			X		
04:00	52,8		1	1	6,0	64,2	64,9		10,9	1	1	11,9							X		
05:00																			X		
06:00														17,7						X	
Shift 2	53,5	8,3	1	1	6,2	65,2	65,4	15,7	11,2	1	1	10,7	17,7	15,7							
Daily average	54,0	8,1	1	1	4,6	65,1	64,9	15,5	11,2	1	1	9,9	17,3	15,5							

Figure 2. Example of a 1-day record file for starch, for germ separation and extraction steps

In figure 2 we also see that the values for organoleptic analysis are recorded with “1” if the smell corresponds to the reference and with “0” if there a faulty smell is perceived, in this last case being necessary to add a comment describing the nonconformity. In this example it was identified that the smell for dried germs, determined at 7:00 o’clock, was not in accordance to the reference value, thus “0” value was input and a comment added in the corresponding cell as “rancid smell”. As other example, for Corn Gluten Feed at 13:00 o’clock a non corresponding aspect was identified, the product being unmilled. In figure 4 we presented an example of a filled table for 1 batch of 10 packaging units from packaging corn germs, corn gluten feed and corn gluten meal. We can observe that for corn germs we have 2 values out of range for

moisture, for CGF packed from “BUNKER A” we have 2 nonconforming values: 1 for aspect unmilled and 1 for protein content. In figure 5 we presented together the tables for record the values obtained for corn starch in bulk and packed in big-bags for 1 shift. We marked with green colour the cells in which the operator should introduce his name, the batch number, the date, the line on which the corn starch is produced and the tank from which the starch is packed. We can observe that the values out of range are marked in red and for organoleptic nonconforming values a comment was inserted describing the deviation. All these 5 files are coded and gathered in a system and from them reports can be extracted to monitor and control each product at a certain time.

Step	GLUTEN SEPARATION			SEPARATION - WASHING - CENTRIFUGATE STARCH SLURRY								
	T.G.		G.P.	S.A.G.	F.G.	L.A.	WATER	L.A.	R.S.	L.A.	L.A.	T.A.
Sample	U(%)	CA%/SU	U (%)	C.(Be)	C.(Be)	C.(Be)	FLOW	FLOW	WATER/L.A.	P(%)	pH	U(%)
Limits	<62	<12	≤ 13	5.0 - 6.0	12.0-17.0	20.0-22.5			1.1-1.3	0.2-0.3	<6.9	<36
Method	PS09	IL-L-03	PS09	ARM	ARM	ARM	FLOWMETER		CALCUL	PS06	PS05	PS09
Frequency	3H	3H	3H	3H	3H	3H	3H	3H	3H	3H	3H	3H
Point	F.C.V.			Usc.	MERKO	W-JRI						CFG.
07:00	63,6		9,8	5,1	13,0	20,5	30	24	1,25	0,21	5,5	33,5
08:00	61,3											
09:00												
10:00	60,8	11,3	10,1	5,3	12,7	20,5	32	25	1,28		5,6	35,7
11:00												
12:00												
13:00	61,2		10,9	5,9	12,5	21,0	30	24	1,25		5,5	36,4
14:00												35,5
15:00												
16:00	60,9		10,5	6,0	12,9	21,0	29	24	1,21		5,7	33,7
17:00												
18:00												
Shift 1	61,6	11,3	10,3	5,6	12,8	20,8	30	24	1,25	0,2	5,6	35,0
19:00	61,2		10,9	5,3	12,7	20,5	29	24	1,21	0,3	5,5	33,5
20:00												
21:00												
22:00	60,8	10,5	10,5	5,9	12,5	21,0	30	24	1,25		5,6	35,7
23:00												
00:00												
01:00	61,3		10,1	6,0	12,9	21,0	32	25	1,28		5,5	35,4
02:00												
03:00												
04:00	60,9		9,8	5,1	13,0	20,5	30	24	1,25		5,7	33,7
05:00												
06:00												
Shift 2	61,1	10,5	10,3	5,6	12,8	20,8	30	24	1,25	0,3	5,6	34,6
Daily average	61,3	10,9	10,3	5,6	12,8	20,8	30	24	1,25	0,2	5,6	34,8

Figure 3. Example of a 1-day record files for gluten separation and starch refining steps

Step	PACKAGING GERMS				PACKAGING CGF								PACKAGING CGM				OBSERVATION	
	Corn Germs				Corn Gluten Feed								Corn gluten meal					
Sample	Smell	Aspect	U (%)	G (%)	Smell	Aspect	U (%)	P (%)	...	Smell	Aspect	U (%)	P (%)	Smell	Aspect	U (%)	P (%)	
Limits	conform	conform	≤ 6.0	≥ 42	conform	conform	≤ 13	≥ 17	...	conform	conform	≤ 13	≥ 17	conform	conform	≤ 13	≥ 58	
Method	S.1	IL-L-23	PS08	IL-L-17	S.1	IL-L-23	PS09	PS06	...	S.1	IL-L-23	PS09	PS06	S.1	IL-L-23	PS08	PS06	
Frequency	Each sample		PM	Each sample		PM	Each sample		PM	Each sample		PM	Each sample		PM	Each sample		PM
Point	BUNKER				BUNKER A				BUNKER D				DRIER					
1	1	1	4,8		1	1	10,5			1	1	10,5		1	1	11,5		
2	1	1	5,5		1	1	10,0			1	1	9,9		1	1	10,7		
3	1	1	5,8		1	1	9,9			1	1	8,9		1	1	10,6		
4	1	1	5,6		1	1	9,6			1	1	9,6		1	1	9,8		
5	1	1	5,5		1	1	8,9			1	1	10,5		1	1	10,1		
6	1	1	5,8		1	1	7,8	unmilled		1	1	9,9		1	1	11,2		
7	1	1	6,2		1	1	8,9			1	1	7,8		1	1	8,7		Identified with red label
8	1	1	6,1		1	1	9,9			1	1	9,9		1	1	9,1		
9	1	1	5,6		1	1	10,5			1	1	10,5		1	1	9,6		
10	1	1	5,8		1	1	9,9	16,8		1	1	9,9	17,2	1	1	9,9	60,8	
Average / batch	1	1	5,7		1	1	9,6	16,8		1	1	9,7	17,2	1	1	10,1	60,8	

Figure 4. Example of a record file for 1 batch of 10 packaging units from by-products packaging step

BULK										PACKED										Packaging type	
CORN STARCH										CORN STARCH											
NAME: _____										NAME: _____											
BATCH: _____										BATCH: _____											
DATE: _____										DATE: _____											
Step	LINE:									Step	TANK FROM IS PACKAGING:									TANK	
Sample	A.N.	A.N.	A.N.	A.N.	A.N.	A.N.	A.N.	A.N.	A.N.	Sample	A.N.	A.N.	A.N.	A.N.	A.N.	A.N.	A.N.	A.N.			
Analyze	Smell	Aspect	P.N./dm ²	Taste	U(%)	Gz. (%)	pH	P(%)	SO2-ppm	Analyze	Smell	Aspect	P.N./dm ²	Taste	U(%)	Gz. (%)	pH	P(%)	SO2-ppm		
Limits	conf.	conf.	≤50	conf.	≤13	≥95	4.5-5.5	≤0.40	≤10	Limits	conf.	conf.	≤50	conf.	≤13	≥95	4.5-5.5	≤0.40	≤10		
Method	S.1	IL-L-23	S.3	IL-L-23	PS09	IL-L-50	PS05	PS06	IL-L-54	Method	S.1	IL-L-23	S.3	IL-L-23	PS09	IL-L-50	PS05	PS06	IL-L-54		
Frequency	3H	3H	PM4(3)	3H	3H	3H	3H	PM4(3)	3H	Frequency	5	5	PM4(3)	5	5	5	5	PM4(3)	5		
Point	DRIER										Point										
07:00	1	1	1		11,5	98,50	5,1		2,00	3	1	1	1	1	9,8	98,3	5,2		5		
08:00										3	2										
09:00										3	3										
10:00					10,1	98,0	5,3		2,00	3	4										
11:00										3	5	1		0	10,7	98,8	5,1		8		
12:00										3	6			1							
13:00	0	1			11,2	98,3	5,4		11,00	4	7										
14:00									9,00	4	8										
15:00									7,00	4	9						4,5				
16:00	1	1			10,6	98,6	4,9		5,00	4	10	1	1	1	10,4	97,9	4,4		8		
17:00										4	11						4,6				
18:00									0,32	4	12								0,34		
Shift 1	1	1	6		10,9	98,4	5,2	0,32	6,00	Average	1	1	1	1	10,3	98,3	4,8	0,34	7,0		

Figure 5. Example of a record file for corn starch in bulk and packed

CONCLUSIONS

A file recording system was created for the use as part of the quality control plan of a starch factory in order to simplify the laboratory results keeping and speed up the decision taking in case of non-conformity, in the benefit of the production process. The system consisting of five files was created by using EXCEL software, which allows simple data input, facilitates the interpretation of the analysis results and minimizes human errors by changing colours of the font or the background in case of wrong data input or in the case of non-conforming parameter determined.

The EXCEL files created simplify the work done by the quality control operator, which can perform the analyses, record the results directly in the computer and report the deviations in a shorter time than before, when the records had to be kept on paper. The new system is more efficient and leads to cost reduction by saving time and reducing errors.

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