The Value of SPC and PC Analytics in Food Processing

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Analytics is seemingly everywhere these days, especially as it relates to Industry 4.0, IoT (the internet of things), and the other technical buzzwords currently in vogue. Analytics is the core of how manufacturing data is transformed into information that drives decisions that impact productivity and food quality.

Of the types of analytics and analytics approaches that are available, statistical process control (SPC) and process capability (PC) analytics seem to receive the least amount of attention in the industry press and at industry events. SPC and PC have been around for several decades and do not enjoy the same cachet these days as the analytics approaches associated with big data. However, they also do not present the same barriers to success as other analytics approaches—namely, high costs, limited usability, and required data scientist–level analytics expertise. SPC and PC may not be flashy, but they provide a foundation for other analytics approaches and have earned their reputation as the workhorse of manufacturing analytics by delivering easily understood and cost-effective analytics for every level of food manufacturing.

SPC and PC are a necessary part of modern food processing. The software selected to satisfy basic food processing needs will determine whether SPC and PC are awkward and intrusive or smoothly operate as part of the overall process.

Software Selection Considerations

The successful implementation of SPC and PC begins with the selection of the tools and methods best suited to a company's quality goals. SPC and PC must not only connect to the data captured and held in a laboratory information management system (LIMS) to produce control charts, but also provide additional capabilities and analysis to production data systems (e.g., manufacturing execution systems [MES], quality systems, and process historians).

Numerous SPC/PC software packages are readily available. Most, however, were created for discrete manufacturing processes such as auto parts machining and, consequently, are limited in their applicability for other manufacturing processes. Food processors evaluating SPC/PC software need to be aware of several key components when selecting SPC/PC software:

- **Usability.** Can the software handle both process and laboratory data? Is the software able to present critical process data in a way that is effective for each user's role in the organization? Will one package meet the needs of all users? Can routine charting tasks be automated to reduce training time? Is unattended operation possible?
- **Data Types.** Can descriptive, measurement, and defect data be viewed in and analyzed from the same data file?
- **Flexibility.** Can charts be configured to precisely meet internal quality control needs and still meet customer and regulatory reporting requirements?
- **Data Access.** Can the software easily analyze data from all sources through industry-standard connectivity technologies? Can it accept instrument data? Can it share or exchange data with corporate or plantwide information systems? Can it easily deliver analytical results and reports to users throughout the organization?
- **In-house Analytics Expertise.** Are the analytics results easily understood by all users, from operators to executives, or is a data scientist required to analyze, interpret, and present meaningful results?

Driving Quality Control and Process Analysis

SPC and PC is used by food companies of all types and sizes, from small independent to major multinational companies. Applications range from internal quality control and process improvement to vendor certification and regulatory compliance.

As an example, in the case of one large food processing company, SPC and PC are used to monitor quality in the dill pickle packing line. Finished jars of pickles are pulled from the production line for routine data collection and charting. Samples are then drained, weighed, and inspected for defects. The description variables entered into a data set are used to label routine SPC charts and provide easy reference points for later process improvement studies:

Description Variables

- ***Date:*** Sampling date
- ***Stock:*** Pickle size being packed
- ***Lot:*** Lot code

Measurement Variables

- ***Weight:*** Drained weight of pickles

Defects and Counts

- ***Count:*** Number of pickles per jar
- ***Nub:*** Nub, crook, misshapen
- ***Broken:*** Broken, mechanical damage
- ***Rot:*** Rot, shriveled
- ***Dirty:*** Dirty, scarred
- ***Size:*** Incorrect sizing
- ***Hollow:*** Hollow

Note, all of this information is collected at the same time and entered into a single data set (Fig. 1), enabling charting to be launched directly from the data entry screen.

The full value of SPC and PC became apparent when the company was considering alternative solutions to a potential supply shortage. The company's standard operating procedure (SOP) for its 46 oz (filled weight) jar required a 3A pickle size ($1^1/_8$ to $1^1/_4$ in.). When supplies ran low, the limitation forced the company to choose between buying more expensive 3A pickles on the open market or changing the SOP to allow use of another stock pickle size, 3B ($1^1/_4$ to $1^3/_8$ in.). If the weight specification could be maintained, the alternate size would be acceptable. To find out, the company conducted a trial run using 3B

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pickles. All of the data needed to analyze 3A and 3B stock could be entered into a single data set.

The apparent success or failure of using 3B stock could be indicated in a PC histogram—a chart showing the distribution of pickle weights and their relationship to specifications. However, the weights first needed to be analyzed using a control chart to verify the packing process was within statistical control. As illustrated in Figure 2, SPC software allows users to display histograms and control charts simultaneously. The x-bar and range chart shows the packing process was within statistical control for both stocks, thus validating the PC study.

Labeling regulations allow up to 20% variation from the target. The Cpk index, a commonly used numeric representation of the capability of a process, showed both stock sizes met production requirements. However, PC does not always reveal the whole story. Another view of the data suggested further analysis was in order.

Because the most commonly used statistical charting techniques can all be launched from a tool bar above the data entry screen, users are able to examine their processes from a variety of perspectives. A routine review of defects using Pareto analysis revealed that the defect "broken" increased during the test run (Fig. 3).

Row	DATE 1----(D)	STOCK 2----(A)	LOT 3----(A)	WEIGHT 4----(I)	COUNT 5----(Z)	NUBS 6----(P)	BROKEN 7----(P)	ROT 8----(P)	DIRTY 9----(P)	SIZE 10----(P)	HOLLOW 11----(P)	TOTAL 12----(P)
1	10/19/95	3A	FD292RA	31	57	0	1	0	0	1	0	1
2	10/19/95	3A	FD292RA	29.5	51	0	2	0	0	1	0	2
3	10/19/95	3A	FD292RA	29	48	0	0	1	0	0	0	1
4	10/19/95	3A	FD292RA	29	48	1	1	0	0	0	0	2
5	10/19/95	3A	FD292RA	30	51	0	1	0	0	1	1	2
6	10/20/95	3B	FD334RB	29	38	1	3	0	0	4	0	7
7	10/20/95	3B	FD334RB	27	36	0	2	0	0	0	0	1
8	10/20/95	3B	FD334RB	29	39	1	2	0	0	0	1	2
9	10/20/95	3B	FD334RB	29.5	42	0	2	0	0	0	0	1
10	10/20/95	3B	FD334RB	28.5	36	1	1	0	0	1	0	2
11	10/20/95	3B	FD334RB	29.5	37	0	5	0	0	1	1	1
12	10/20/95	3B	FD334RB	28	36	1	3	0	0	0	1	2
13	10/20/95	3B	FD334RB	30	40	0	4	0	0	2	0	2
14	10/20/95	3B	FD334RB	28	33	1	2	0	0	0	1	1
15	10/20/95	3B	FD334RB	28	39	0	2	0	0	1	0	1
16	10/20/95	3B	FD334RB	29.5	35	1	1	0	0	3	1	2
17	10/20/95	3B	FD334RB	26	33	0	2	0	0	0	0	2
18	10/20/95	3B	FD334RB	30	37	1	3	1	0	0	2	1
19	10/20/95	3B	FD334RB	27	38	0	3	0	0	2	1	0

Fig. 1. Statistical process control (SPC) and process capability (PC) analytics data collection and charting for monitoring quality. Information is collected at one time and entered into a single data set.

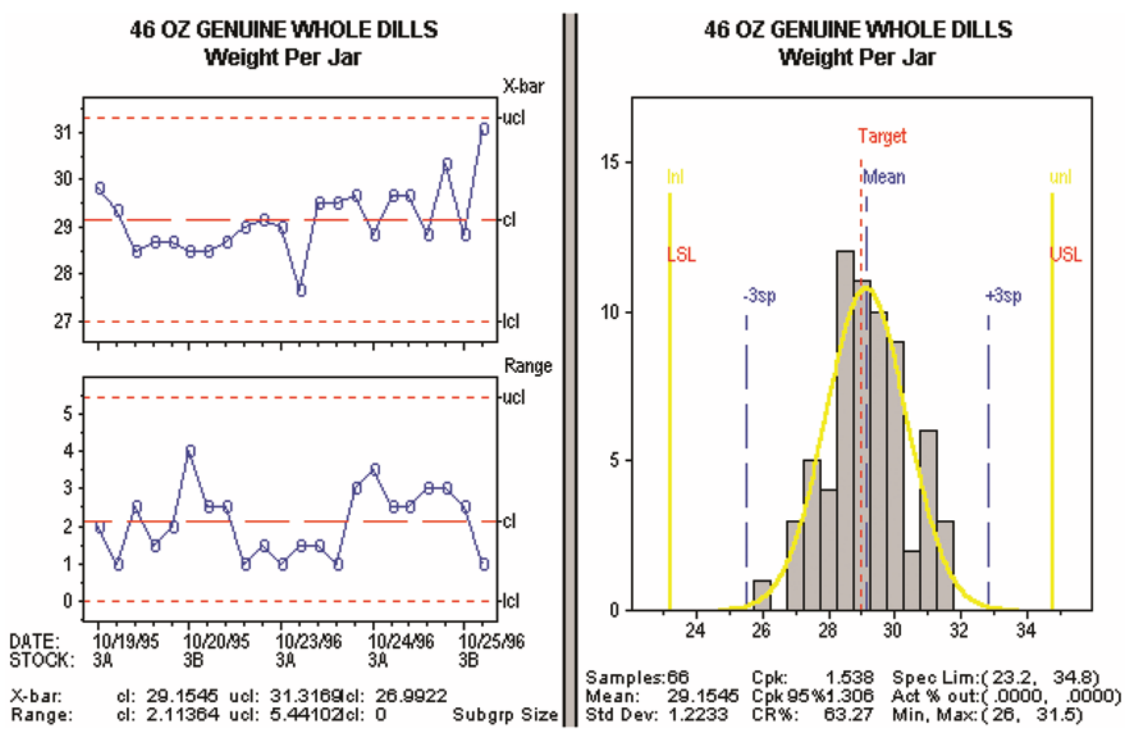

Fig. 2. Left: process capability (PC) histogram chart showing distribution of pickle weights and their relationship to specifications. Right: control chart used to analyze weights and verify packing process is within statistical control.

For further analysis, the lab produced a p-chart (percent defective SPC chart) (Fig. 4) and found two points above the upper control limit. Pattern rule violations, shown on the chart by asterisks, provided further warning. The operator then clicked on each suspect data point to "drill down" for more information. The resulting dialogue boxes pointed to the 3B stock. Separate p-charts for each stock type quickly confirmed 3B stock as the source of the unacceptable levels of breakage (Fig. 5).

Further study revealed that 3B pickles frequently had to be forced into the jar, causing breakage. However, the p-chart showed the process itself to be within statistical control, because breakage was a natural part of the process. The processors concluded that although the 3B stock could be used to remain in label weight compliance, breakage might be excessive.

From Data to Information

Using the information provided by the analyzed data, the processor drew several conclusions:

- They could maintain statistical control and process capability while using either or both pickle stocks.
- Excessive broken pickles resulted when using larger 3B stock.
- SPC analysis of broken 3B stock pickles showed the process was within perfect statistical control; this meant the higher breakage rate was characteristic of the process and was not attributable to any specific cause.

With a clear understanding of their packing process, the company recognized they had three distinct choices:

- Live with the breakage and risk customer displeasure.
- Continue to study the process to determine whether the process could be modified to reduce 3B breakage in a cost-effective manner.
- Meet shortages by continuing to purchase 3A stock on the open market.

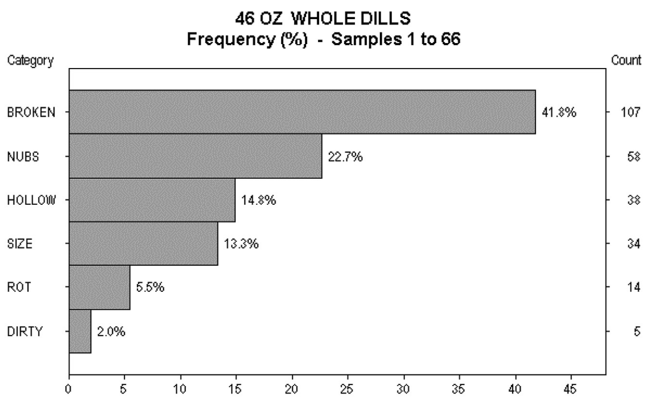

Fig. 3. Pareto analysis used to review defects shows the defect "broken" increased during the test run.

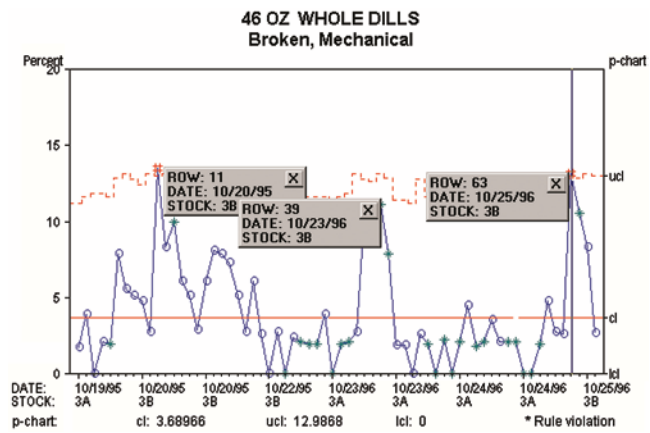

Fig. 4. Analysis using a p-chart (percent defective statistical process control [SPC] chart) shows two points above the upper control limit.

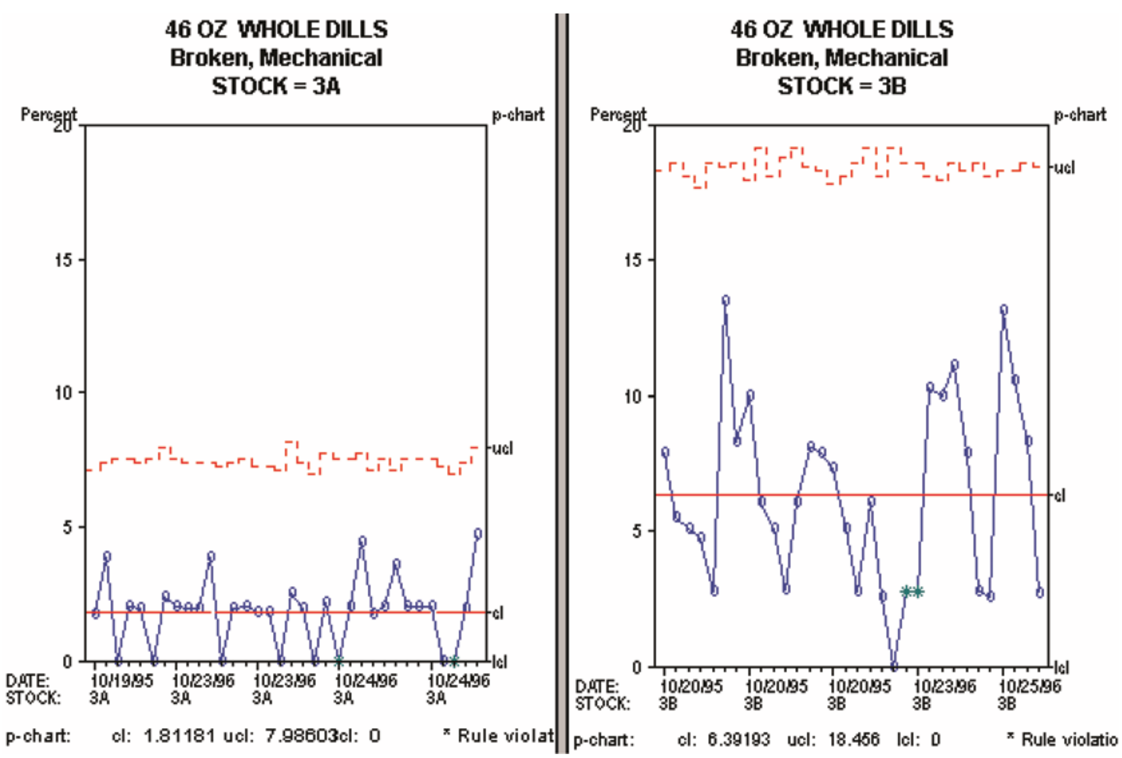

Fig. 5. Separate p-charts for each stock type confirm 3B stock as the source of unacceptable levels of breakage.

SPC and PC delivered valuable information to all levels of the organization, helping both managers and production staff to understand their processes and enabling them to make confident decisions that impacted both product quality and costs.

Application-Specific Charts

Two special-purpose charts that apply to the food processing industry are cumulative sum (CUSUM) and median/individual measurements (M/I) control charts.

CUSUM and Regulatory Requirements. CUSUM produces a control chart based on the accumulated deviations from a target (Fig. 6). It is particularly well suited to examining processes that may "drift," and it can be tuned to different levels of sensitivity. It is especially useful in regulated industries such as meat and poultry processing. For example, as the U.S. Department of Agriculture (USDA) adds CUSUM methods to inspection procedures, such as the protein fat-free (PFF) regulations, CUSUM charting routines can be adjusted to match new requirements.

M/I and Fill Weight Control. The M/I chart solves the SPC challenges presented by "family" processes such as multihead filling machines in which multiple individual processes (separate fill heads) are combined within a larger process (Fig. 7).

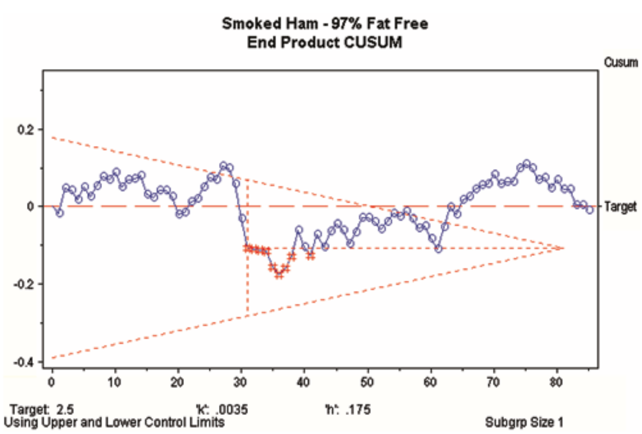

Fig. 6. CUSUM (cumulative sum) produces a control chart based on accumulated deviations from a target.

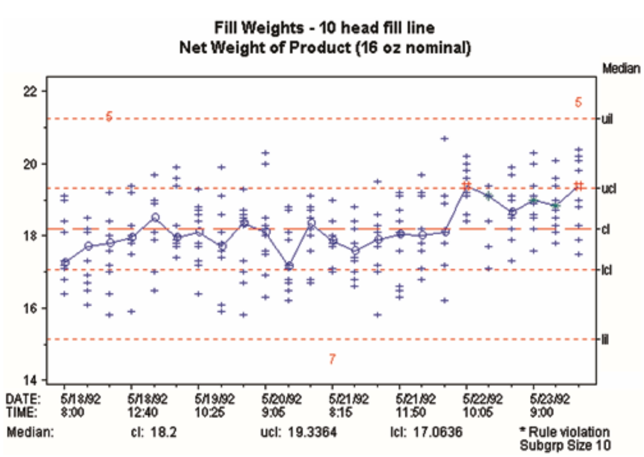

Fig. 7. Median/individual measurements (M/I) charts used for "family" processes such as multihead filling machines in which multiple individual processes (separate fill heads) are combined within a larger process, allowing users to simultaneously monitor the overall process and behavior of individual fill heads.

With conventional control charts, it is virtually impossible to separate the behavior of the individual heads from the global process. To completely monitor a 36 head filling machine, 37 charts would be needed—1 per head and 1 for the overall process.

M/I charts allow users to simultaneously monitor the overall process and the behavior of the individual fill heads. The resulting chart is easy to read and interpret and is far quicker to create than the alternative. (An in-depth examination of M/I charting capabilities and applications can be found in *Median/Individual Measurements Control Charting*, by Perry Holst and John Vanderveen, developers of the M/I technique.)

SPC and PC Provide a Foundation for Analytics Success

SPC and PC may not be the latest-and-greatest analytics approaches in food manufacturing, but they deliver what other analytics approaches cannot: a defined path to quickly improve quality, reduce variation, monitor production or process changes, and ultimately increase productivity. The successful selection and implementation of SPC/PC software in a food processing environment does not require the level of commitment that MES or enterprise resource planning does (in terms of time, personnel, expertise, and financial resources) to deliver actionable results and quick returns on investment. In addition, once a solid analytics foundation is built with SPC and PC the chances of attaining the additional benefits promised by more esoteric big-data analytics approaches increase as well.

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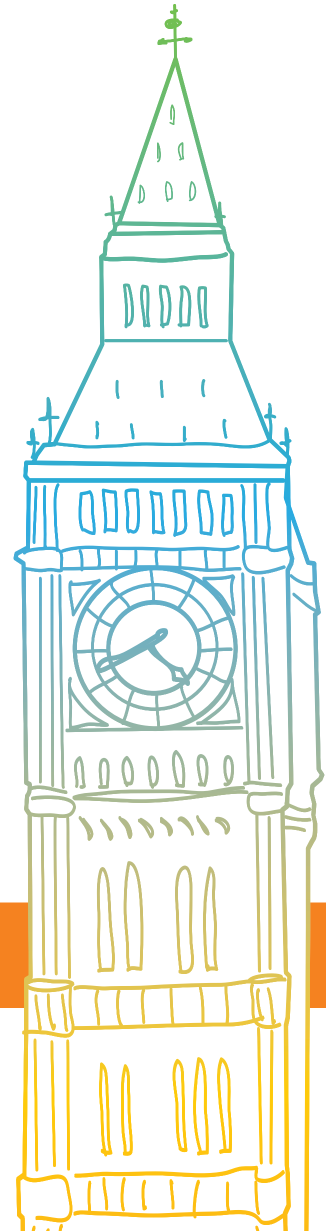

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