Characterizing Denim Shrinkage

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Keywords: denim, shrinkage, product quality, loglinear variance

Introduction. Fit is crucial for an apparel manufacturer's profitability as ill-fitting garments lead to higher return rates (Ashdown, 2011). Fit is controlled by specifying garment dimensions, but textile production complicates the ability of any manufacturer to remain within tolerances (Douhib et al., 2016; Khedher et al., 2013). This study applies loglinear variance analysis to data from Khairnar (2019) seeking to understand denim shrinkage, by investigating shrinkage data for 3 denim fabrics and 4 washes. The methods described could be applied to other business cases to identify combinations of factors which may lead to difficult to control quality.

Related Literature and Theory. Starting as work wear, denim jeans have become an iconic and highly demanded piece of fashion becoming a product category capable of supporting international companies (Paul, 2015; Farashahi et al., 2018). Denim production for the American market is largely outsourced to Latin America and Asia (Allen & Huffman, 2005). While outsourcing has advantages in reduced labor costs and machinery access, remote cut and sew operations complicates quality control processes (Yang & Lindsay, 2011). Clear, measurable, and enforceable standards are crucial for outsourced production.

Fit affects the wearer's comfort, mobility, and the overall style of the garment and is therefore crucial to control (Csanak, 2015). The dominant method of monitoring a product's fit during production is through standards for garment dimensions (Csanak, 2015; Sieben & Chen-Yu, 1992). Typically, major circumferences such as the waist and hip are allowed to vary by +/- 0.5 inches and garment lengths to vary by +/- 1-inch reflecting higher sensitivity to variation in circumference (Sieben & Chen-Yu, 1992; Ashdown & DeLong, 1995).

Sieben and Chen-Yu (1992) found 76.4% of jeans fell outside these tolerances. One of the causes was shrinkage during production. Fabric laydown and sewing both may cause a garment's dimensions to shrink (Douhib et al., 2016; Khedher et al., 2013). Manufacturers must also contend with chemical interactions. The cotton fibers in denim absorb and release moisture causing shrinkage (Csanak, 2015; Cryer, 1935). Jeans also feature a variety of finishes and treatments such as stone washing, bleach, and enzyme washing which similarly cause shrinkage (Nazim, 2019). To compensate for the shrinkage, garment patterns are routinely altered prior to cutting by enlarging patterns by the expected shrinkage amount (Bilbic & Duru Baykal, 2016). This method relies on fabric behaving in a consistent manner to achieve a consistent sizing, so reduction of variance is key for improving garment quality. (Bilbic & Duru Baykal, 2016).

Results and Discussion. The data for this study comes from Khairnar (2019). Her data were analyzed with fixed effects models and no tolerances, as opposed to loglinear variance modeling. In her study, she worked with one denim brand company where samples of three types of denim were marked with 18x18 inch squares and subjected to 4 different types of garment wash. The denim types were 100% cotton (CC), a polyester/cotton bi-blend (BB), and a polyester/cotton/spandex tri-blend (TB). The wash types were rinse (LB), cold bleach (LT), hot bleach (BT), and stone wash (ST). Each combination of fabric and wash were tested 8 times and percentage of shrinkage was recorded by a single operator. The results for dried samples were recorded in JMP. Denim is not a square fabric, so any suitability judgements must be made considering both directions of shrinkage. As shown in Table 1, the CC fabric exhibited the lowest shrinkage overall. The BB and TB fabrics exhibited more shrinkage in the fill direction.

The data were analyzed with loglinear variance modeling with fabric and wash used as mean and variance effects to estimate the shrinkage mean and standard deviation. In Table 2, the Suggested Pattern Dimension used a standard 32 inch target dimension and increased it by the specific mean shrinkage for each fabric-wash combination. The Minimum and Maximum Expected Dimensions form the 95% confidence intervals for shrinkage.

The interval formed by the Minimum and Maximum Expected Dimensions was compared to a standard tolerance interval of 32+/-0.5 inches. Fabric and wash combinations likely to fall outside of the tolerance interval were identified and highlighted. The CC fabric treated with a rinse is the least likely to present quality control issues while the BB fabric with cold bleach poses issues in both the warp and fill directions.

Table 1: Average shrinkage observed by fabric and wash combination

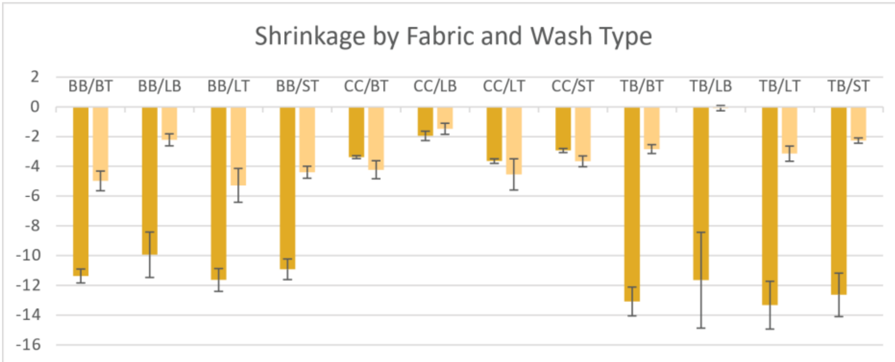

Table 2: Suggested pattern dimension and 95% confidence interval predictions for range of garment size

Fabric	Wash	Suggested Pattern Dimension (Fill)	Minimum Expected Dimension	Maximum Expected Dimension	Suggested Pattern Dimension (Warp)	Minimum Expected Dimension	Maximum Expected Dimension
BB	BT	36.11	31.67	32.33	33.68	31.55	32.45
BB	LB	35.53	30.91	33.09	32.73	31.74	32.26
BB	LT	36.21	31.45	32.55	33.78	31.23	32.77
BB	ST	35.92	31.50	32.50	33.47	31.73	32.27
CC	BT	33.12	31.94	32.06	33.41	31.59	32.41
CC	LB	32.64	31.80	32.20	32.48	31.76	32.24
CC	LT	33.21	31.90	32.10	33.52	31.30	32.70
CC	ST	32.97	31.91	32.09	33.22	31.75	32.25
TB	BT	36.82	31.29	32.71	32.94	31.81	32.19
TB	LB	36.22	29.66	34.34	32.03	31.89	32.11
TB	LT	36.92	30.81	33.19	33.04	31.67	32.33
TB	ST	36.63	30.93	33.07	32.74	31.88	32.12

Implications. Results show textile and wash combinations can vary beyond tolerances. Loglinear variance identified which combinations will not be controllable, adding to Khairnar (2019) findings. In this study, a bi-blend product with cold bleach washing could be washed before cutting due to the variance. While this study focused on one denim manufacturer, the methodology could be applied to other cases.

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