THE EFFECT OF BATTER MIXING TIME ON PANCAKE FLUFFINESS

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ABSTRACT

While there is a general consensus that mixing time affects the consistency of pancakes, the optimal mixing time to create the desired 'fluffiness' in American-style pancakes has not yet been firmly established. To investigate this relationship, the effect of increasing batter mixing time on pancake fluffiness was measured using the force taken to compress each pancake as well as their thickness. A texture analyzer was used to compress each pancake by 5mm, and calipers were used to measure thickness. The batches of batter were created using the same ingredients but were mixed for different times within the range of 20-90 seconds. As mixing time increased, the compressive force increased exponentially resulting in nearly a factor of 1.3 increase in force at 90s compared to 20s (hypothesized mean difference). Thickness peaked at 20.76 ±0.44 mm after 45±3s with maximum fluffiness occurring around 42 ±6s. The overmixing threshold occurs after 60s of mixing time as fluffiness declines rapidly by a factor of 4.

Keywords: Pancake, Batter, Mixing, Gluten, Thickness

INTRODUCTION

American-style pancakes can take many shapes and forms with one of the most desirable being an iconic, fluffy stack of them. Pancake recipes provide many differing opinions on how long you should mix your batter for before beginning to cook. The phrases 'mix in a lot of air' and 'we strongly urge you to not overmix' are commonly stated within pancake recipes but are slightly contradictory given their vague nature. Both claims are made to avoid obtaining a flat pancake, but no real line of distinction has been drawn as to how long mixing should take to create the fluffiest version of your pancake recipe. Research has been conducted on how varying the ingredients in pancake batter, such as the type of flour used, affect pancake properties, but none were solely dedicated to mixing time. Mixing time has the ability to alter pancake batter composition on a molecular scale [2] and thus will have an impact on whether you are able to have a stack of fluffy pancakes or a stack of flat flapjacks. The conclusions drawn from examining how mixing time affects pancake fluffiness would not only be applicable in household kitchens but also in the restaurant industry as 'fluffy' pancakes are more appealing to consumers – which is seen emphasized in advertisements from places like IHOP.

In this research paper, the effect that increasing mixing time has on pancake fluffiness was investigated by incrementing mixer time by 10 seconds (starting at 20 and ending at 90) and measuring the resultant 'fluffiness'. 'Fluffiness', in this case, being thickness(mm) over compressive force(N) as a higher thickness and lower compressive force equate to higher fluffiness. A Stable Microsystem TA.XT Plus Texture Analyzer was used to find the amount of force taken to compress each pancake by 5mm, and calipers were used to find pancake thickness. To make this experiment replicable, the design was kept simple and parameters such as pan temperature, volume of batter per pancake, mixer speed, and time on the heat remained constant within my controlled environment. The raw data was extracted and analyzed in MATLAB.

BACKGROUND THEORY

In this section the underlying science behind this relationship between mixing time and fluffiness is explained. Subsection 1 describes what is happening to the pancake batter's molecular makeup as the ingredients are mixed together. Subsection 2 looks at similar research papers on pancake fluffiness and compares any similarities or differences seen in procedures or findings.

THE GLUTEN STRUCTURE IN PANCAKE BATTER

In order to create pancakes, batter must first be created from a mix of both dry and wet ingredients. Pancake dry mix consists of baking powder, salt, sugar and most importantly flour. Flour is created from wheat which contains two strands of protein called glutenin and gliadin

[2]. When in the presence of water, these two proteins are able to bond to each other and ultimately form an intertwined gluten structure [2]. This network helps to trap gas or air bubbles that enable the pancake to rise and is displayed in Figure 1.

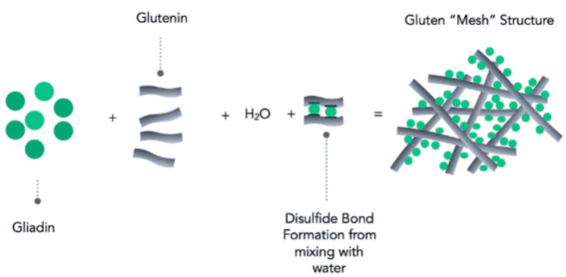

Figure 1: Diagram showing two proteins in dry pancake mix, glutenin and gliadin, linking together into a gluten network when water is added and stirred together into batter. [4]

It is commonly believed that you can create a fluffier pancake by incorporating more air, which is true for the pancake to rise but doesn't account for what will happen to the gluten with continued mixing. As the batter is mixed, the protein strands begin to interact even more with the water, thus overdeveloping the gluten, which tightens the protein structure and destroys the air bubbles that were initially beaten into the batter [2]. The pancake will turn out chewy as it takes on the elastic properties of the gluten [2], which is not ideal when the goal is a light, fluffy pancake. Therefore, examining how mixing time affects pancake fluffiness is important as we can determine a ballpark stopping point for batter mixing to avoid these implications.

RESEARCH EXAMINING PANCAKE PROPERTIES

Prior studies have evaluated how changing the type of flour (each having a different gluten content) affects pancake fluffiness, which directly connects to what is being investigated here when evaluating the gluten structure which is altered via mixing. In this study we examine how overmixing will overdevelop the gluten and cause a physical change to occur in the pancake, which is related but different to the research papers on this topic.

In a paper written by V.K. Yemmireddy, the physico-chemical properties of pancakes containing different amounts of peanut flour were examined [3]. A texture analysis was run on the pancakes which is similar in nature to what will take place in this project. One parameter which is examined is hardness which is the "..peak force (N) required to compress the specimen to a depth of 5 mm from its original height." [3]. This is what was utilized to determine by comparison, which pancakes were fluffier than others when looking at different batter mixing times.

Another research paper, written by Eunjin Cho, examined the influence that the choice of flour has on pancakes but also altered mix time [1]. This paper examined the springiness and cohesiveness of the pancakes in relation to the flour used and found that "Springiness and cohesiveness of baked pancake were under negative correlation with mixing time of Mixograph." [1]. This is directly related to the effects of mixing time on pancake composition and will serve to bolster the argument against overmixing. This negative correlation can be seen in Figure 2 below. Springiness being "the ration between the height of the first compression and the recovered height after the first compression" as the pancakes were compressed to half their initial height at 1mm/s [1].

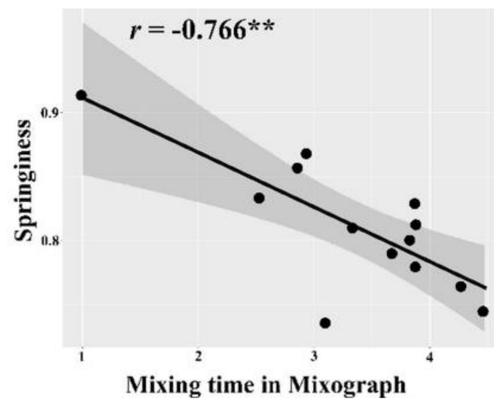

Figure 2: Scatterplot showing springiness of pancake versus the mixing time in Mixograph for 13 different kinds of wheat flours. The measurement/unit of time is not given in this graph in the paper, but the general downward trend of the line is clear and serves to show the relationship between the two variables. [1]

EXPERIMENTAL DESIGN

In this section the experimental setup of this research is described. Subsection 1 describes the pancake making procedure and Subsection 2 describes how the force and thickness measurements were obtained for the pancakes.

MIXER AND COOKING SET-UP

1 cup of dry pancake mix and ¾ cup of water were initially placed in a large metallic mixing bowl, without any stirring occurring. It was then put in a KitchenAid Professional 6000 HD Mixer (6QT 1.0 HP Motor) on its lowest speed, which remains constant throughout this

experiment. This was the amount of batter used to create 5 pancakes per mixing speed evaluated. The amount of time spent in the mixer was varied, starting with 20 seconds, which is the amount of time it took to just mix in all the dry mix (lumps still present), and increasing by increments of 10s up to 90s. Figure 3 shows the batter mixed for 20s with the lumps and the batter mixed for 90s without.

Figure 3: Figure (a) showing the batter at the point of just mixing in the dry mix at 20 seconds and figure (b) showing the batter after mixing for the maximum 90s. There are noticeable textural differences as batter(a) has a dough consistency and batter(b) has a runny ketchup consistency.

For each mixer time, the batter was then scooped out of the bowl using a ¼ measuring cup and poured straight into the center of the pan to form the pancake (after lightly spraying the pan surface with cooking oil spray). The temperature of the pan was kept constant at the medium electric stove heating setting of 5. The pancake was allowed to cook on one side for 2 minutes, then flipped back into the center, and allowed to finish cooking with an additional minute and a half before being taken off the stove and allowed to cool to room temperature on a platter. The platters holding the five pancakes per mixer time were labelled accordingly by their mixing time.

TEXTURE ANALYZER AND THICKNESS MEASUREMENTS

Once all the pancakes were cooked, they were sealed off in designated containers for each mixing time and immediately transported over to campus for analysis. No pancake stacking occurred in these containers as that would end up affecting the results. All the pancakes were placed next to each other or on a different level within the container, created using cardboard spacers. In this experiment, the amount of force(N) it would take to compress a pancake by 5mm using the Stable Microsystem TA.XT Plus Texture Analyzer was measured. This force is then used to determine 'fluffiness', as a larger compressive force needed to press down on the pancake indicates a tougher pancake. Test Mode was set to Compression, Pre-test Speed = 5.00 mm/sec, Test Speed = 2.00 mm/sec, Post-test Speed = 10.00 mm/sec, and the distance compressed set to 5mm upon being triggered by a force of 5g.

Each pancake was placed on the stand right below the compression probe (TA-4 1, RM:3- 038) and is shown in figure 4. The program in Exponent was then run, and each pancake was compressed 3 times according to the specifications already listed. The data, consisting of the force taken to compress each pancake against time, was saved in an excel sheet named 'Excel_PancakeData.xls'. The thickness (mm) of each pancake was also measured using calipers and documented within this excel sheet in order to calculate the relative fluffiness of the pancakes in each mixer time region later on.

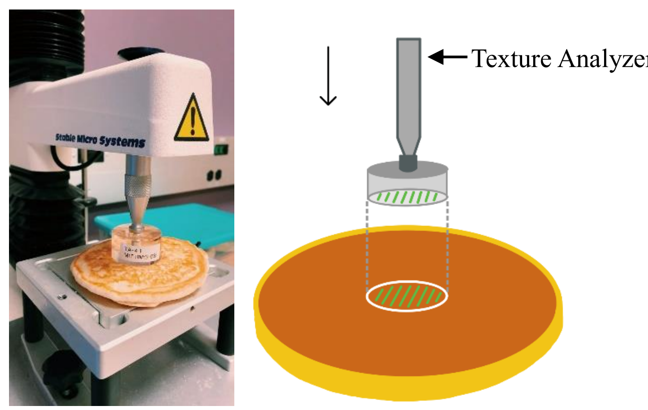

Figure 4: (a)Photograph of a pancake being compressed by 5mm using a Stable Microsystems Texture Analyzer probe with a supporting stand below. (b) Diagram showing a pancake being compressed by a Stable Microsystems Texture Analyzer probe at the center point of the pancake shape.

ANALYSIS METHODS

In order to find the maximum force needed to compress each pancake, data was gathered from Exponent. The application created graphs of the force(g) needed to compress each pancake by 5mm against time(s) when connected to the TA (Texture Analyzer). This was imported into Excel, making sure to separate each mixer time data into different sheets. Force was then recalculated in Newtons and the Excel function MAX was used to find the maximum force needed to compress each pancake (3 times), within each mixer time sheet. The function AVERAGE was used to find the mean value of the max forces, STDEV to find the standard deviation, and the t value was found to be 2.145 (using the table with n of 15 and v of 14).

Before creating the plots in MATLAB, the uncertainty was calculated in these averages using the equation: uncertainty = (SD)*t/(√n). A scatterplot graph of the mean peak forces per mixing time with error bars, indicative of these uncertainty values, was created. Another scatterplot graph of thickness(mm) versus mixing time was also created and with a parabolic curve fit to all the values. Finally, Fluffiness was calculated using the expression thickness(mm)/peak force(N), shown in Equation (1), as a larger thickness and lower compressive force is what 'fluffiness' is classified as. A quadratic curve was fit to this data and the point of maximum fluffiness was found with uncertainty.

$$\text{Fluffiness (mm/N)} = \text{Thickness/(Peak Force)} \qquad (1)$$

RESULTS AND DISCUSSION

Figure 5 shows the thickness of each pancake sample for the mixing times 30, 50, 70 and 90s. The thickness was modelled using a parabolic curve that peaks at around 20.76 ±0.44 mm after 45±3s and then takes a drastic decline with increased mixing time above 60 seconds. These measurements were used later in the calculation of fluffiness.

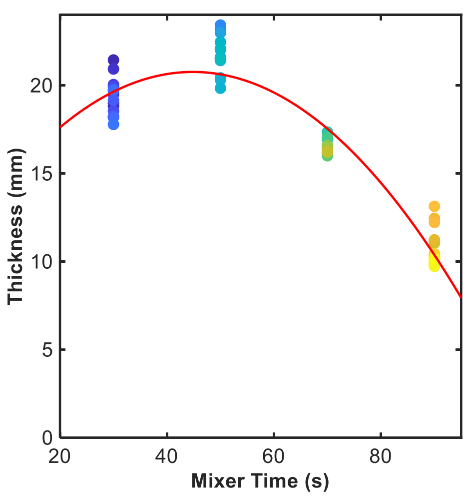

Figure 5: Scatterplot showing the thickness(mm) of each pancake made with batter mixed for 30, 50, 70, and 90 seconds. Equation of curve: Thickness = a*((t-h) ^2) +k (a = -0.00510 ± 0.00080, h = 44.9 ± 2.8, k = 20.76 ± 0.45).

The texture analyzer was then used to evaluate compressive force (g) over mixing time. The raw data collected from Exponent generates a graph of force (g) versus time (s) for all the pancake measurements in each mixer time section. Figure 6 shows how this raw data was translated into singular graphs (one per curve) with the force calculated in Newtons. The peak compressive force on each curve was extracted from these graphs and recorded in an Excel sheet for further analysis.

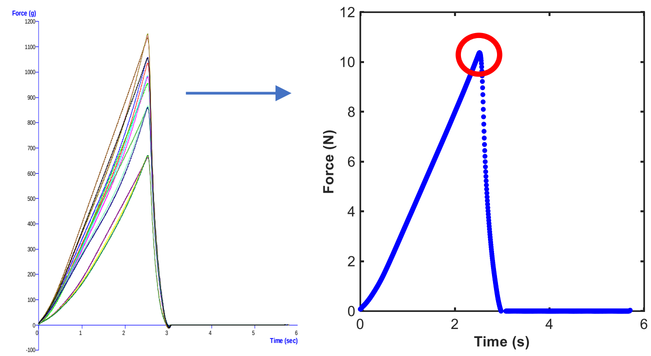

Figure 6: (a) Graph straight from Exponent showing the compressive force(g) needed by TA to push down each pancake made with a mixer time of 20s, for reference. Each colored curve is a different compressive test on a different pancake. (b) Scatterplot graph of raw data from one pancake, within the 20s mixer time, undergoing one compressive test of the TA (the multiple readings in (a) are similar in composition). The red circle indicates the maximum force(N) attained to compress the pancake by 5mm.

When all the raw data was taken together, the average peak forces per mixer time were found with uncertainty and plotted in the form of a scatterplot with error bars in Figure 7. It shows force (N) against each set mixing time (s). Between times 20s to 60s the average peak force increased very slightly, however, there was significant error bar overlap. There seems to be a much larger, exponential increase in average peak force between 60 and 90s, as the average values at 70, 80 and 90s are statistically different from one another with 95% confidence. This coincides with the previous researched background data that predicts tougher (less fluffy) pancakes with increased mixer time. The point of overmixing/overdeveloping the gluten and popping the air bubbles within the protein network of the pancake is likely to occur above 60s of mixing time as is shown by both Figure 5 and 7.

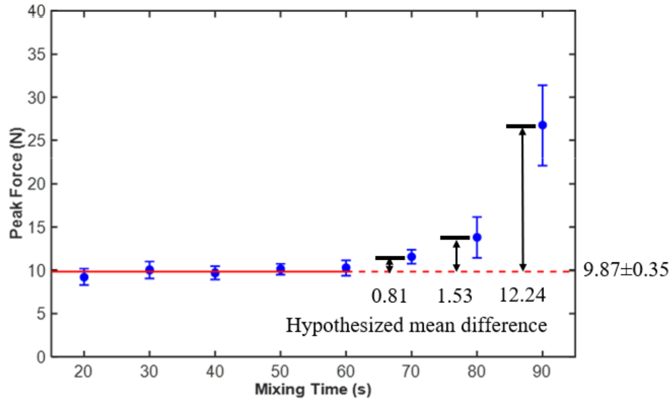

Figure 7: Scatterplot showing the peak force(N) needed to compress pancakes whose batters were mixed for 20 to 90 seconds. The error bars indicate the uncertainty in the measured averages. The solid red line shows the average of the peak forces between 20 and 60s and extends further as a dashed line that shows the hypothesized mean difference between the batches mixed for 70, 80 and 90s and those mixed for 60s and lower.

When combining the data from thickness(mm) and compressive force(N) measurements, a scatterplot graph of fluffiness(mm/N) was created. The fluffiness data in figure 8 takes a quadratic fit with a maximum value at 42±6 seconds. This graph exhibits the initial assumption that pancake fluffiness would increase with mixing time and then begin to decline once a threshold of overmixing is reached. This point of overmixing occurs once at least 60 seconds of mixing has taken place and the pancake fluffiness becomes negatively affected.

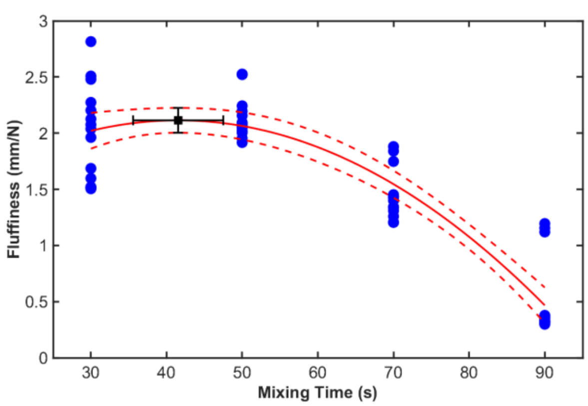

Figure 8: Scatterplot showing fluffiness(mm/N) versus mixing time(s). The solid red line indicates the quadratic fit with the dashed red line as uncertainty. The maximum point is shown as a black square with error bars. Maximum fluffiness occurs at 42±6s.

CONCLUSION

The data found matches the original hypothesis that increasing mixer time will increase pancake fluffiness up to a certain point as you begin to overdevelop the gluten. The final figure reveals a point in time at which true overmixing will occur and begin to negatively affect pancake fluffiness to a much greater degree than in previous time intervals. Fluffiness reaches a maximum point around 42±6s of mixing time and will begin to decline rapidly when the batter is mixed for more than 60 seconds due to both a rapid increase in peak force and reduction in thickness.

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