

**BME 200/300**

# **Measuring Caloric Intake Using Chewing Sounds: Final Report**

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## **I. Abstract**

Current methods of tracking caloric intake dietary monitoring rely heavily on subject memory, often an unreliable source of accurate data. The possibility of analyzing chewing sounds recorded in the ear canal was recently considered as a possible aid to subject memory. Sounds produced during chewing are conducted well in the ear canal due to bone conduction through the mastoid process. When positioned properly, a small microphone can record sounds and, through analysis, the basic type or consistency of the food can be determined, such as crunchy, moist, or soft. Designs are proposed that explore the possibilities dietary monitoring using chewing sounds, considering microphone placement, amplification methods, and signal analysis. The final design targets optimum conditions for recording chewing sounds, and the analysis has led to reasonable accuracy in determining food types eaten for simple, fairly homogenous foods.

## **II. Summary of Gathered Information**

Caloric intake analysis has been and continues to be a major focus of research. One important study done by involved the analysis of three different textures of food, defined as: soft, wet-crisp, and dry-crisp. This study also demonstrated some success recording chewing sounds by placing the microphone at different locations: in front of the mouth, by the throat, in the ear canal, by the cheek, outside the ear, and behind the ear. The results of this particular study showed that different types of foods produced different frequencies of sounds when they were chewed. Additionally, reasonable success was shown in determining the type of food consumed, with the exact food consumed

being determined in 60% of the tests. In the majority of the trials, patterns in the recorded signal could be utilized to detect the start of a chewing sound (Amft *et al.* 2005).

Other research includes a study of the acoustics of a normal swallow, or cervical auscultation, and its properties. In Australia, a group of researchers determined how the age and gender of a subject, as well as the size of the bolus (the amount of food swallowed) related to his/her swallow. From the data collected, they were able to conclude that the swallowing frequencies were similar for both males and females of different ages when the same amount of food was swallowed. Furthermore, the group was able to show that the sound produced when swallowing was between 0 and 8 kHz, with the length of the swallow being up to 0.8 s. The most relevant results of this study were that the most intense swallowing sound signal occurred almost exactly 1 s after the first signal detection of chewing without a great deal of variation in terms of age, gender, or bolus volume (Cichero and Murdoch 2002). This study shows that analyzing swallowing sounds may be an easier method of monitoring dietary intake due to its low variation among test subjects.

Various types of instruments were used to perform the studies mentioned, some of which were not cost-effective. For example, the study carried out by Amft (2005) used an expensive microphone with high sensitivity and wide frequency response. In one Australian study, scientists used two acoustic detector units consisting of an accelerometer and a Knowles microphone. This device was able to record sound frequencies effectively, but was utilized in a soundproof laboratory. Unlike these studies, the analysis of chewing sounds to determine caloric intake cannot be limited to the laboratory, so larger, expensive instrumentation is not always necessary for this research.

### **III. Design Problem**

In recent years, the incidence of weight-related disease, such as diabetes and cardiovascular disease, has increased dramatically. This increase directly correlates with an increase in the proportion of overweight and obese people in the population. Consequently, much effort has been channeled into finding ways to monitor dietary and exercise habits in the general population.

Measuring caloric expenditure has been facilitated by invention of devices such as the pedometer. However, measuring caloric intake has been a more daunting task. Current food consumption data typically relies on the subject's memory and willingness to share information. This method allows for patient forgetfulness or bias to effect the accuracy of the data. For example, patient bias may exist in a society where excessive intake of unhealthy foods may have negative connotations; a person may feel the compulsion to change his/her intake data to reflect him or herself in a more positive light.

In order to strengthen the value of the data, more accurate ways of measuring and gathering caloric intake data are needed. Our team explored the possibility of recording and analyzing chewing sounds in an effort to facilitate a more accurate analysis. A small, cost-effective microphone with an adequate frequency response was used to record chewing sounds within the ear canal. After recording, the data was filtered to isolate chewing frequencies, which are distinguishable from other noise, such as speech. The chewing sounds were then characterized by their frequencies and amplitudes, which could be correlated with foods possessing different textures. We hoped that this microphone, along with other devices and methods of analysis, would create a device that

increases the reliability of food intake data. The device would serve as a memory aid for the subject and allow for the accuracy of the data to be examined to some extent.

#### **IV. Materials and Methods**

##### **IV-i. Recording**

The majority of chewing sounds for this study were recorded within the ear canal, although several external locations were experimented with. The chewing sounds within the ear canal were captured with small gel probes designed to work with an Audioscan audiological microphone. The gel probes were very soft and could be inserted a short distance into the ear canal with little risk. In the ear canal, the probe is somewhat sheltered from ambient sounds and exposed to the chewing sounds, transmitted there efficiently through bone conduction. The gel probes were adapted to work with small, cheap microphones, for a more cost effective design. The signal was then passed to through an amplification and filtering phase, consisting of either a amplifier pack or simple circuit.

The amplifier filtered out the DC component of the signal, which contained no information related to the sounds recorded, making the signal easier to analyze. The pack also amplified the signal, which was originally of a very low amplitude. Most audiology microphones include their own packs to which the microphones are easily connected. The amplifier pack was electrically shielded and showed little influence from external noise. The alternative to this pack, the circuit design, was fairly simple and could be produced with common circuit components, although measures had to be taken to shield

the device. After the amplification phase filtered and amplified the signal, it was sent to the oscilloscope.

The signal that was transmitted to the oscilloscope was a time-varying voltage signal recorded by the microphone, containing the chewing sounds. The signal had two components, a frequency and amplitude, which vary with the changing sounds that are recorded. Using the oscilloscope, the signal could be viewed and the values of the frequency and amplitude could be determined. When the oscilloscope was interfaced with a computer through Microsoft Excel, the signal was digitized and stored in an Excel spreadsheet as a series of data points where it could be further analyzed.

#### **IV-ii. Processing and Analysis**

Once chewing sounds were recorded, they were analyzed to determine what type of useful data they contained. It was expected that foods with different compositions and textures would create different types of sounds when chewed, with different characteristic frequencies and amplitudes. The frequency of the sounds was analyzed using a Fourier Transform, which allowed the data to be viewed the frequency domain. This allowed for an analysis of the various frequencies present in the signal and their respective amplitudes. By viewing chewing sounds in the time and frequency domain, a great deal of information about the type of food that the subject is eating could be determined. By sampling a large variety of food types and textures and analyzing the chewing sounds that were produced, methods were proposed to identify when chewing takes place as well as what type of food the subject is eating.

## **V. Alternative Solutions**

The proposed designs experiment with several locations where chewing sounds can be recorded. We considered one internal location: the ear canal, and two external locations: the mastoid process (behind the ear) and on the throat. The various locations were compared and analyzed based on the quality of signal attainable and the level of risk and subject comfort.

Placing the microphone directly on the throat was infeasible. Accordingly, the microphone would be attached to a piece of attire, for example, the collar of a shirt. In order to place the microphone in closest proximity with the mastoid process bone, the probe module could be attached to the ear. The attached probe would be positioned behind the ear and kept in place by adhesive surgical tape.

As in the in-ear microphone design, the entire microphone system would be attached to an oscilloscope that would record chewing sounds. The data collected would be analyzed with Excel, specifically with the Fast-Fourier Transform algorithm.

## **VI. Preliminary Evaluation of Alternative Solutions**

### **VI-i. In-Ear Probe Microphone Design**

There were several advantages to the placement of the Audioscan probe microphone inside the ear canal, an important one being that it was able to record the chewing sounds clearly because of its placement near the jaw. Also, because the microphone was placed inside the ear, there was low exposure to ambient noise.

Further analysis of this internal microphone design alternative indicated the disadvantages of the idea. First of all, the method is somewhat invasive, as the probe tube



must be inserted into the ear. Although the gel probes that are used are very soft, there is still some risk associated with inserting the probe into the ear canal, especially with excessive insertion. Secondly, if the probe tubes were not disposed after use by one subject, use of the same tube by a different subject could have led to transmission of bacteria, and as a result, could cause ear infections. There was also an issue with the cost of the device. The microphone system we received, the Audioscan RE-720A, was received as a donation was no longer being produced. A similar device manufactured by Etymonic Design Inc. costed approximately \$1500



**Fig 1.** Audioscan Microphone pack. The microphone portion has a small loop that fits around the ear. The amplifier pack can be connected to the oscilloscope.

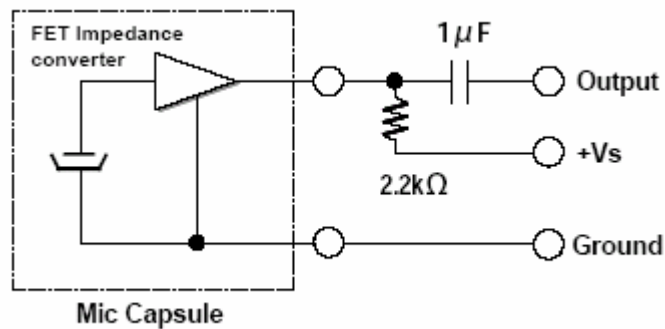
#### **VI-ii. External Microphone Design**

An external microphone offers several advantages for recording chewing sounds, including greater safety and subject comfort. The greatest advantage the external designs offer is that no components must be inserted into the body. This noninvasive nature

eliminates many of the hygienic concerns of using a probe tube in the ear canal. Also, subject comfort with both the feel and idea of the device will most likely be greater with an external recording location.

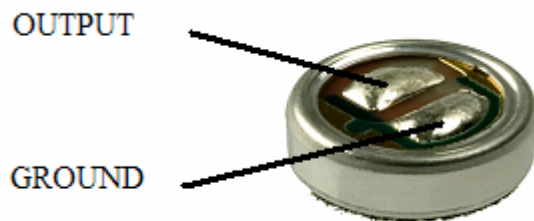
There are some disadvantages associated with external recording locations. One important disadvantage was that the external microphone would be more exposed to the external environment compared to the internal microphone. This external location would naturally be more susceptible to external noise, clouding the signal. This ambient noise would have affected the readings produced by the chewing sounds and would not have produced accurate results of the user's chewing. In general, external locations are less able to take advantage of bone conduction, which transmits chewing sounds very effectively. External locations are often farther from major portions of bone mass, shielded by fat, skin, and other tissues. Despite the ergonomic advantages of the external design, the poorer signal acquisition compared to that of the in-ear recording make external recording locations inferior.

## VII. Final Prototype

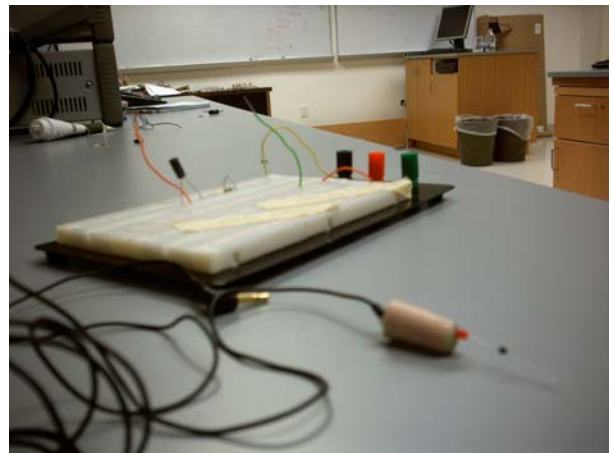


**Fig 2.** Circuit for Pre-soldered Microphone, contained within the microphone enclosure.

As a more cost-effective alternative to the Audioscan microphone, a replacement in-ear microphone was developed. This less expensive system consisted of a miniature electric condenser microphone purchased from Digikey, which provided the necessary frequency response to capture all possible chewing sounds. The microphone had a rated frequency range of 20 Hz to 20 kHz while operating at 2V and consuming 0.5 mA. The lead from the output terminal of the microphone was connected to the input of the oscilloscope and the second microphone terminal was grounded along with the ground lead of the oscilloscope. The resistor in the circuit provides a voltage division to allow for the proper voltage of 2 V to power the microphone.



**Fig 3.** A picture of the miniature microphone before connections are attached



**Fig 4.** A simple circuit designed to power the microphone.

The ergonomics of the microphone had to be considered in the design to avoid damage to the eardrum of the subject. Foam ear filters were purchased and modified in order to make space for the microphone to be embedded. A canal through the center of

the ear filter was created and the microphone was secured inside with a two-part epoxy. A silicone ear probe was extended through the other end of the ear filter and cut to an appropriate length to facilitate placement within the ear. This microphone was later used to test the ability for our program to detect the type of food being chewed.

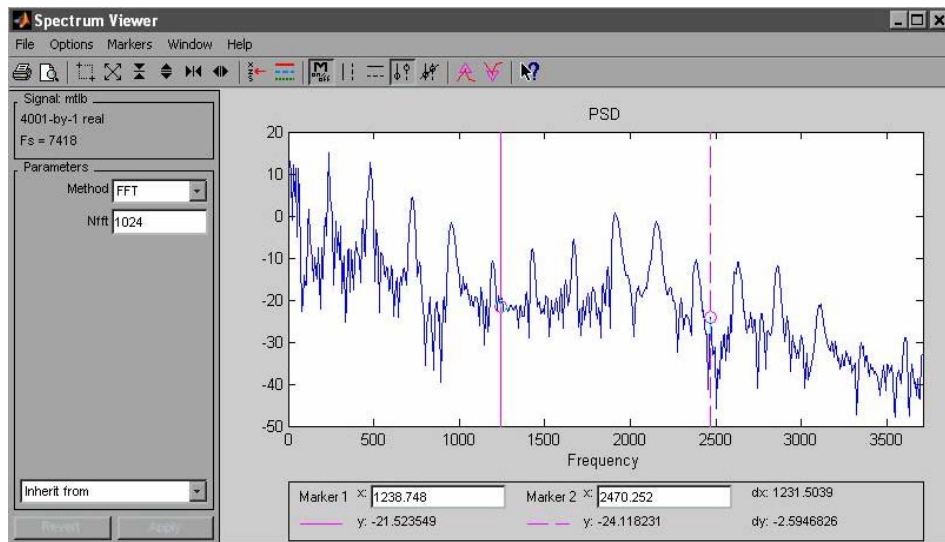
### **VIII. Data Acquisition and Analysis**

In order to standardize the chewing data, only one subject was used to gather chewing waveforms for all the different foods. The Audioscan microphone generated the cleanest and most distinct signals; therefore, it was the microphone used to create a database of audio signals for different types of foods. The subject ate a variety of different foods representing the general overall consistency spectrum, from soft to crunchy. Once multiple samples were taken, they were analyzed for characteristic patterns and differences.

It was discovered that the initial bite of food showed the most distinction between the different types of foods and a more consistent response, so our study focused on distinguishing the various foods solely by analysis of the initial bite. The first bite most likely provides the most consistent results since food is most uniform in consistency before chewing. Chewing then breaks down various parts of the food, creating a more heterogeneous mixture and less consistent results.

The waveform data was visualized on an oscilloscope, where the screen could be pause and the values imported into a Microsoft Excel spreadsheet through a General Purpose Interface Bus (GPIB) connection between the oscilloscope and the computer.

In order to avoid aliasing of the audio signal, the sampling frequency was set at 40 kHz to capture 40 000 samples of the waveform per second. This frequency is at least twice the highest frequency contained in the chewing waveform, as frequencies above 10 kHz were not observed in any of the foods. According to the Nyquist-Shannon sampling theorem, with the sampling frequency as such, the sampled signal should be an undistorted reconstruction of the true waveform. The Excel spreadsheet in which data was entered contained a Visual Basic macro that was edited to be able to analyze the captured chewing data. The spreadsheet also contained time domain plot of the audio waveform along with the frequency domain plot.



**Fig 5.** Spectral analysis of speech in MATLAB

The frequency domain plot was achieved through the Fast Fourier Transform (FFT) algorithm contained in the Data Analysis Toolpack in Microsoft Excel. The magnitudes of the complex coefficients generated by the FFT were plotted versus the frequencies to generate the spectrum of the signal. Matlab, a data analysis and signal

processing application produced by The Mathworks™, was initially used to perform the signal processing and the data analysis, but it proved difficult to automate.

The waveform from the oscilloscope was directly captured into Excel spreadsheet and as a result, Matlab processing also required extra steps of importing and exporting data. The macro features in Microsoft Excel, which were written in the Visual Basic computer language, allowed for automation events to trigger when the user presses a button, so the analysis only required a single button press when the macro program was executing.

## **IX. Solution (Summary of Reasons)**

Our final design considers all of the components necessary to accurately and cheaply record and analyze chewing sounds in the ear canal. Given that the microphone must be placed near the mouth to maximize exposure to mastication sounds, the ear canal provided the most appropriate positioning. This location provided the isolation from ambient noise and direct exposure to bone conduction necessary for quality recording. Although slightly more invasive, recording chewing sounds within the ear offers options in terms of comfort: many devices fit comfortably in the ear without interfering with normal life. Our device used a commonly worn ear filter, modified to contain a microphone with a probe tube attachment.

Initially, we had used a sophisticated and very expensive Audioscan audiological microphone, which contained its own amplifier, to record chewing sounds. Although this device is good for research purposes due to its high quality recordings, it is not a cost-effective option to modify for our purposes. After exploring our options, the best

microphone was a simple electret condenser microphone with a wide frequency response. At less than \$5.00 for the microphone, it provided the necessary equipment for a small price. This microphone also included the necessary amplification and needed no added circuit amplification. The only modification necessary was to alter the voltages delivered to the microphone, done with a simple circuit board.

Finally, analysis proved an important and formidable task for this project. In early analyses, Matlab coding was the easiest option since it provided the functions and tools necessary to quickly analyze large amounts of data. Soon, however, we discovered that this process would not easily be automated and that a lengthy protocol would be necessary. Excel analysis then provided the needed analysis and also allowed for automation using macros and the built-in data analysis toolpack. Using Excel's Fast Fourier Transform (FFT) algorithm, we were able to analyze data at a fast pace (though slower than Matlab) but without a great deal of work on the user's end.

## **X. Data and Results**

After the microphone was constructed and tested to ensure proper frequency response, testing actual chewing with the microphone began. Given the nature of human subject testing, we obtained Institutional Research Board (IRB) approval in order to use ourselves as test subjects. Using one subject, we used the Audioscan audiological microphone to obtain a set of recordings to use as a database. The subject ate six different foods, including an apple, a banana, rice, bagels, and crispy potato chips to use these as models for various food types. Using the voltage vs. time data collected in

Excel, we used our analysis spreadsheet containing the FFT algorithm to determine peak voltage of each food.

Using the peak frequencies output by our Excel spreadsheet as indicators of the food type, we developed a correlation between food type and the peak. As mentioned, different types of foods produce different sounds in the ear canal, and these sounds can be differentiated, we discovered, based on the maximum amplitude of the Fourier transformed data. We divided the frequency range of 0 to 2000 Hz by what types of foods had characteristic peaks in those regions. This gave a spectrum of frequencies for which we could test our microphone for its ability to record the chewing sounds. As well, this also tested the repeatability of the experiment and the accuracy of our FFT algorithm.

After gathering more data using the prototype microphone and testing it against our database developed from the Audioscan microphone, we found strong, detectable differences in peak frequencies. As a result, the Excel macro was able to determine the food type with surprising accuracy. Though we were not able to collect enough data to determine any meaningful statistics on the data, the trends that we noticed indicated that the device does, in fact, have potential to detect food sound with very high accuracy. Nonetheless, at times, the food type detected by the algorithm was very similar to the actual food consumed, such as confusion between eating an apple or a potato chip or rice and a bagel. Such errors occurred less frequently than accurate results, however.



## **XI. Interpretation of Results**

Analysis of the data revealed an interesting correlation between food type (texture) and peak frequencies observed in the initial chew. For example, the initial chew of an apple corresponded to a frequency of 1650 Hz, that of a chip corresponded to a frequency of 1550 Hz, while that of soft, cooked rice corresponded to a frequency of 400 Hz. Generally, hard foods (chips, pretzels) were associated with higher peak frequencies, while soft foods (cooked rice, bagel) were associated with lower peak frequencies.

As mentioned above, the peak frequency for an apple chew is 1550 Hz, quite close to that of the chip at 1650 Hz. Since each initial chew can be different (even in the same subject), the program constructed in Excel is designed to interpret ranges rather than a point value. Since the peak frequencies for the apple and chip are so close, it is quite possible that the ranges for these frequencies overlap. Therefore, the program may confuse the identity of the food in cases where the initial chew peak frequencies are similar.

Ramifications of the confusion mentioned above are widespread. If the device is not capable of distinguishing between chews from an apple (a healthy food) and from a chip (an unhealthy food), its scope as a direct measure of caloric intake is limited. However, it is worth noting that the program designed has been accurate in most instances (statistical data is not yet available; more data points have to be collected), even in distinguishing the identity of an apple vs. a chip.

In the current stages of development, we can confidently declare that our prototype will serve as an excellent memory aid. It will track the textures of the food

consumed. With some data that suggest what type of food was eaten at a certain time, the subject may be more able to recall details about his/her meals.

Further development of the prototype and analysis protocol will eliminate confusion. Since the device is calibrated to each individual (a sample database of a variety of foods is recorded before any recording of actual chewing data is performed), this should narrow the range of characteristic peak frequencies for certain foods. Another possible modification to the process involves recording more data points. This will serve to highlight differences in chewing frequency characteristics, even in similarly textured foods.

## **XII. Conclusion**

When developing design solutions to record chewing sounds, there were several ethical issues that we had to take into consideration regarding the health and welfare of the users of the device. One major factor is the comfort of the user. First of all, there is the possibility that the user will have to remain seated for long periods of time in order to obtain the necessary data to analyze the chewing sounds. In this case, he/she will need to be provided with comfortable seating. Secondly, there is also the requirement that the microphone be placed in a comfortable position. If the microphone is placed inside the ear canal, it would need to be placed inside something soft to avoid causing irritation in the ear. That is one of the reasons why we decided to place the microphone inside an ear filter (ear plug). Also, care needs to be taken that the probe tube is not inserted too far into the ear canal that it punctures or bruises the eardrum. This is why, with our final design, the probe tube that is protruding out of the ear filter will need to be shortened so

that, when the entire microphone-probe tube system is placed inside the ear, the probe tube will not come in contact with the ear drum.

Apart from user comfort, another major ethical factor to take into consideration with this project is hygiene. When using the microphone with a probe tube that is inserted into the ear, it is important to ensure that one probe tube is discarded after being used by a subject. If more than one subject utilizes the same tube, there is the chance that bacteria from fluids will be transmitted from person to person. These bacteria can, in turn, cause ear infections, contributing to pain and extreme discomfort.

The team was able to accomplish the important goals of this project over the course of the semester. First of all, we were able to interface the microphone to the oscilloscope and the computer and obtain signals from normal speech as well as some initial chewing. To do this, we used the Audioscan microphone. But we decided that such a microphone is too expensive and planned to use a small, cheap microphone with along with probe tubes as a more cost-effective design alternative. After receiving approval from the IRB, we were then able to record frequencies of the sounds that were produced from chewing of various types of foods, including soft foods, such as bagels and rice, and crispy foods, such as chips. These waveforms were then captured by Microsoft Excel and converted to a frequency domain by performing a Fast Fourier Transform in Excel also. This module was also able to determine what type of food was consumed from analyzing an observed chewing frequency and identifying a frequency range within which it belonged. Different frequency ranges were assigned for different food textures.

In the future, more research would be needed to determine more specific relationships between chewing sounds and their associated foods. Our methods of

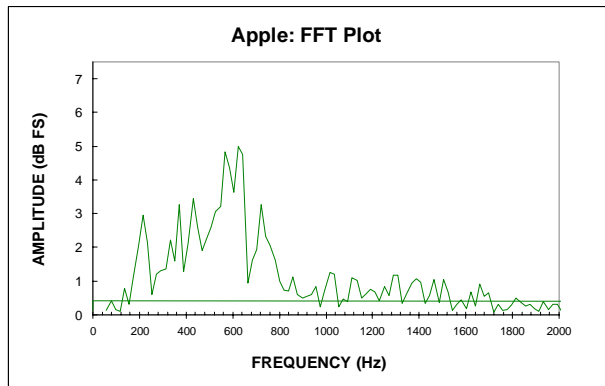
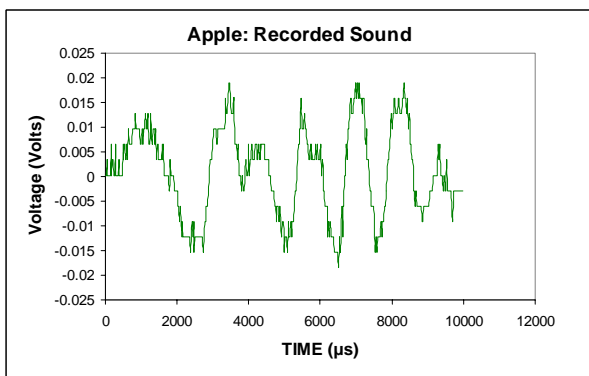
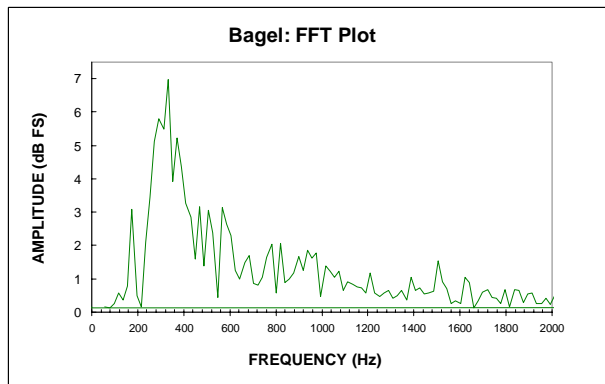
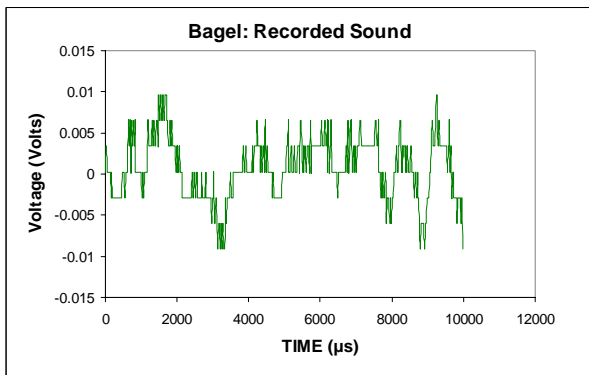
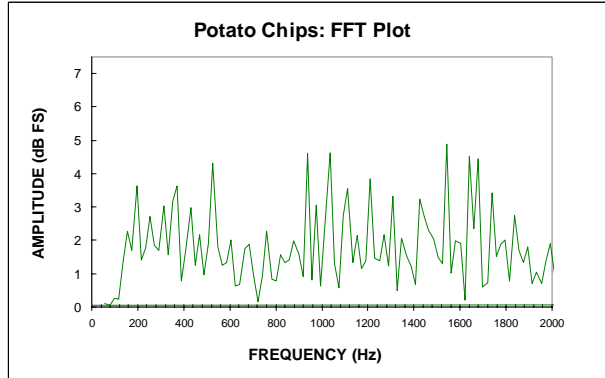
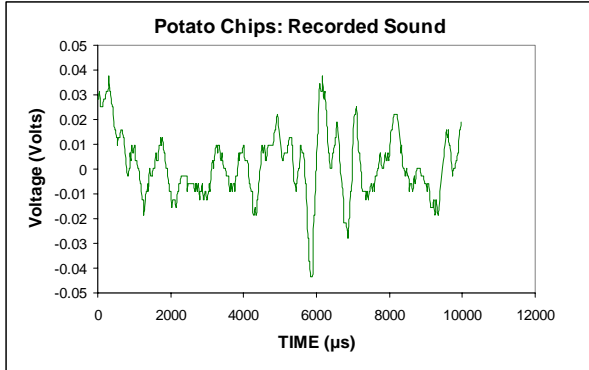
analysis were limited to the first chew, which was characterized by its frequency and amplitude. There may be other characteristic patterns that appear over the course of several chews that may be useful in characterizing foods, although we feel these patterns may be less consistent. We also focused on foods that were fairly uniform in consistency. Foods with mixed food types and consistencies that are eaten at once could not be identified without more sophisticated analysis, although eating times could still be identified.

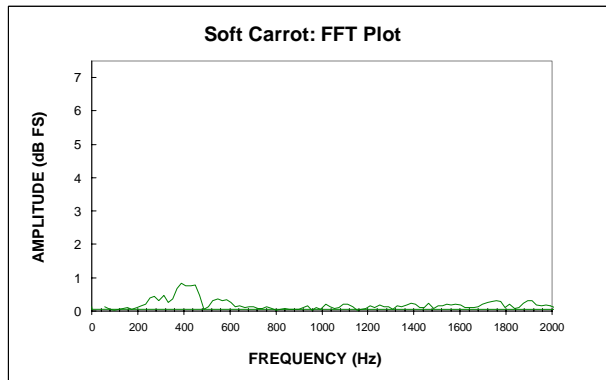
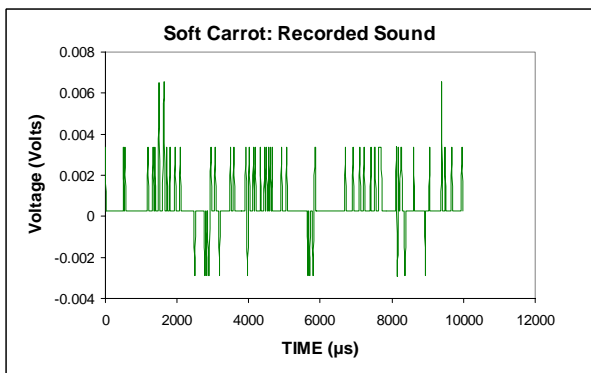
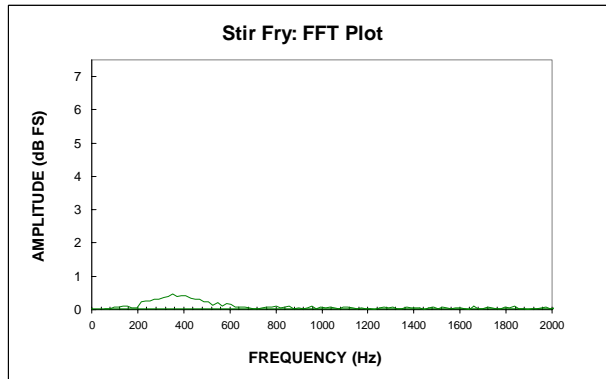
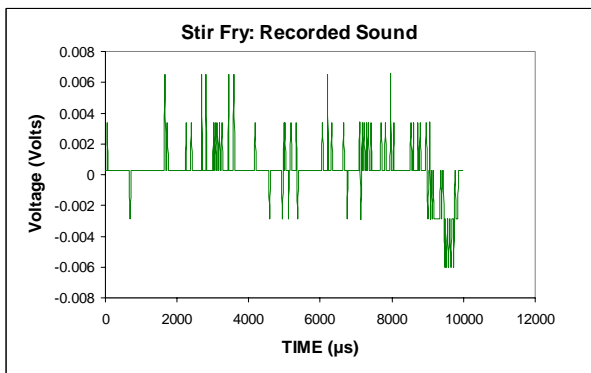
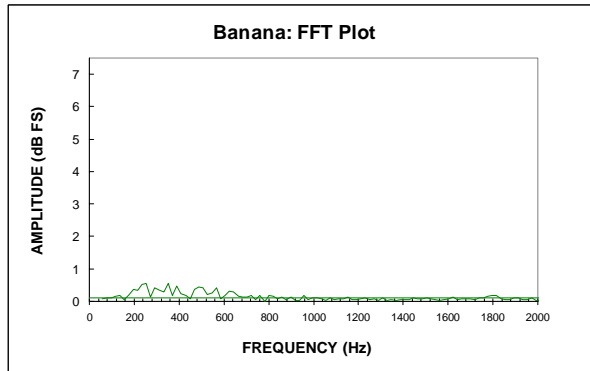
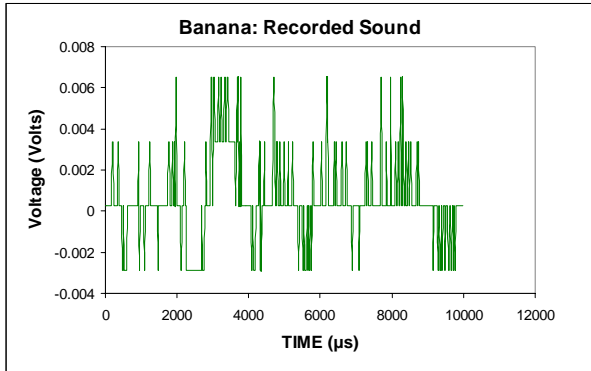
We were not able to devise a way for the computer to determine the number of calories in a food based on the frequencies of the chewing sounds produced when this food was consumed, so this is something that can be investigated. However, the ultimate goal is to create a device that will be able to perform these tasks but will be portable, so that users can carry it around wherever they go and will serve as a caloric intake monitor. Our work so far shows that recording chewing sounds through the ear canal has the potential to form the basis of a portable device that could be worn throughout the day to aid the user in accurate reporting of dietary intake.

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# Appendix





## **Team 43: Chewing Sounds- Product Design Specification**

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### **1. Background Information**

Close to one-third of all Americans are obese. (<http://win.niddk.nih.gov/statistics/index.htm#whydodiffer>) Many researchers are developing ways to prevent this alarming number from growing. Monitoring caloric input and output are the main goals; analyzing habitual dietary and exercise data will help predict trends in obesity. Monitoring caloric output has been explored extensively. The pedometer, for instance, is a common tool that aids in measuring expended calories. Monitoring food intake has been a daunting task; many people rely on their memories to describe what they ate. To portray a better image of themselves, they may even lie about some of the foods they have eaten.

### **2. Function**

In order to obtain more accurate data, our team is exploring the possibility of recording and analyzing chewing sounds. We will need to find an effective microphone that is capable of recording different chewing sounds at differing frequencies. After recording the data, we will need a way of filtering the data so that it is distinguishable from background noise (speech etc.). After the filtration, we should be able to relate certain intensities/frequencies of chewing sounds to the consumption of foods possessing different textures. In concert with other devices, we hope that the microphone will be a tool in monitoring dietary intake, paving the way for a healthy lifestyle.

### **3. Client Requirements**

- Create a tool that accurately records what people eat, when they eat it, and where they eat it.
- To record the chewing sounds, either utilize a microphone that is placed inside the ear or some other location, such as near the mouth.
- The device should be able to distinguish between when a subject is chewing and when he/she is swallowing.
- The ability to record chewing sounds should be able to be performed numerous times.
- The chewing and swallowing sounds should also be able to be differentiated from other background noises.

If and when we have accomplished these requirements, Dr. Schoeller has some additional requests. They are:

- That the device is able to distinguish between what types of food are consumed, such as crunchy and soft foods.



- The device is able to identify the food and the number of calories that the subject consumes.

#### 4. Physical and Operational Characteristics

- a. Performance Requirements:** The device used to detect chewing sounds will have use in the laboratory setting, but it has the potential to become a portable device after much initial testing. Using this device, we will record sounds and store this data until transmission to a computer source. Given the preliminary status of this experiment, the design will be used only in the laboratory and should experience minimal wear. The microphone will be placed into the ear by the user and will remain there for the period of testing, possibly as long as an hour.

Sounds produced by chewing can be detected by air- and bone-conduction. Frequency analysis of air-conducted sounds from chewed potato chips in the Amft study showed frequencies between zero and 10 kHz although the frequency range with highest amplitude for various crisp products are in the range of 1 kHz–2 kHz. The soft tissue of mouth and jaw damp high frequencies and amplify at the resonant frequency of the mandible (160 Hz) when chewed with closed mouth (Amft, *et al.* 2005). The device should have a frequency response of approximately 20 Hz to 2 kHz.

- b. Safety:** In order to correlate foods to their sound patterns, we must test the device extensively using human subjects.

The risk of perforating the eardrum through the insertion of a microphone into the ear canal is minimal because the microphone will be placed far enough from the eardrum and still capture bone conduction. Furthermore, the construction of the device should be such that there is no risk of the microphone slipping farther into the ear canal and possibly puncturing the eardrum. One risk with the microphone, however, is the spread of infection by use of the same earpiece by numerous subjects. An infection could lead to puncture of the eardrum, but sanitary habits should prevent any possible exposure to these types of infections (All Refer Health).

Another issue to be considered is the possibility that the microphone becoming lodged in the canal. Problems that can result from this include pain and discomfort. Additionally, temporary hearing loss can occur since the ear canal and eardrum are occluded. The microphone would need to be removed immediately to restore hearing.

Contact transmission of infection through devices such as headphones, hearing aid and probes is a potential health concern. The risk of developing infection is great if the hearing device is not sterilized in between subjects.

Not sterilizing the microphone between uses provides microbes an easy access into the ear orifice, establishing infections quickly, especially in people with a weaker immune response. Also, when bare hands are used in removing hearing tools, the risk of transmission is increased, as microbes are capable of entering the body through epithelial tissue. A safe way is needed to interface the subject and the microphone (Infection Control in Audiological Practice).

- c. **Accuracy & Reliability:** Previous studies (Amft, *et al.* 2005) have achieved 80-100% accuracy in food determination, and we hope to replicate and improve upon these results.
- d. **Life in Service:** Since this field has not received a great deal of attention, the device will have to perform for hours at a time in order to obtain enough analyzable data. The sound detector will have to perform for many hours in the laboratory and for many weeks (and months if this study continues).
- e. **Shelf Life:** Shelf life is not a concern in this stage of the project since our goal is to obtain, analyze and report data. This will become a concern once the design of a prototype has commenced.
- f. **Operating environment:** The device must operate effectively in a lab environment. This environment may include noise sources including external sounds and subject movement and speech that should not hinder the device from operating effectively.

In the field, the device must operate effectively in a reasonable temperature, pressure, and humidity range that the subject could be exposed to in their everyday life. External noise or other influences such as speech, ambient sounds and subject movement should not hinder detection of chewing audio.

Battery life at a minimum must last the length of an average waking day, or roughly 16 h.
- g. **Ergonomics:** In the eventual development of a prototype, the microphone and recorder should not impede with the normal daily activities of the wearer.
- h. **Size and Weight:** The device must be of portable size, shape, and weight. Carrying the device throughout the day should not place undue burden on the subject.

The average ear canal is 26 mm long with a 7 mm diameter, and as such, the microphone must have approximately a 7 mm diameter. If a microphone tube is used, it must not extend more than 20 mm. (U.S. Department of Labor Occupational Safety & Health Administration)

- i. Materials:** The three components of our analysis are: the microphone, recorder and an analyzer (computer).
- j. Aesthetics, Appearance, and Finish:** Ideally, the device would be small and relatively unnoticeable to both the subject and others so it could be carried inconspicuously throughout the day.

## **5. Production Characteristics**

The goal of this project is to record and analyze data more so than to develop and market a prototype. This preliminary work is necessary so that in the future, a prototype may be developed.

## **6. Miscellaneous**

- a.** No information found about national/international standards and specifications.
- b.** As this project involves human subject testing, we will need to get approval from the IRB (Institutional Review Board Services), even though we will only be testing amongst our own team. One of our clients, Dr. Schoeller, has offered to obtain this approval.
- c.** As the microphone will be placed in the ear canal, it may need to be sterilized after testing each subject.
- d.** Monitoring dietary intake is a novel idea. Although studies of chewing data have been published, a product with the client's specifications has not been marketed. No competition is anticipated.