PROCUREMENT, PROCESS, AND STORAGE TECHNIQUES FOR CONTROLLING OFF-GASSING AND PELLET TEMPERATURES

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ABSTRACT

The main aim of this research document is to better understand the reasons for temperature increases and off-gas emissions from stored wood pellets. Numerous studies have been conducted on the off-gas emissions from wood pellets, but very little has been done on the natural heating process in storage facilities and how it can be controlled both in operational and procurement practices. The rationale behind this document is to better understand the relationship between both off-gassing and the heating of pellets in the storage facilities. There have been reported deaths, injuries and fires as a direct result of off-gassing and the spontaneous heating of wood pellets in both storage facilities and shipping vessels in the previous years. With this paper the goal is to better explain how a pellet production facility along with storage and shipping facility can better control post production temperatures and off-gassing utilizing better procurement and process techniques.

KEYWORDS

- **Exothermic Reaction:** is a chemical reaction that releases energy in the form of heat.

- **Condensation:** is the change in the phase of matter from the gaseous phase into liquid droplets.

- **Fatty Acid:** is a carboxylic acid with a long unbranched aliphatic tail which is either saturated or unsaturated.

- **Lignen:** is a complex chemical compound most commonly derived from wood, and an integral part of the secondary cell walls of plants.

- **Autoxidation:** is any oxidation that occurs in open air or in the presence of oxygen and forms peroxides and hydroperoxides.

- **Volatile Organic Compound (VOCs):** refers to organic chemical compounds which have significant vapour pressures and which can affect the environment and human health.

- **CO:** colourless, odourless and tasteless gas which is lighter than air. Produced from the partial oxidation of carbon-containing compounds.

- **CO_2:** is a chemical compound composed of two oxygen atoms covalently bonded to a single carbon atom.
- **CH_4:** Methane is the simplest alkane, and the simplest principle component of natural gas.

- **Aeration:** the forced movement of ambient air of suitable quality or of suitably conditioned air through a grain bulk for improvement of grain storability.

INTRODUCTION

Today there are numerous mills either in development or under construction throughout the southeast mainly due to the abundance of southern yellow pine. With all the mills being constructed and most companies focusing more on the pellet production and wood procurement processes; the storage of the finished product is almost an afterthought. Without proper storage the highest quality pellet will not be of any value once it reaches its port of call overseas. By utilizing enhanced procurement procedures, specific production techniques, and understanding the mechanics and physics of modern pellet storage management companies can ensure the best product is delivered to their customers overseas. All three areas have to be taken into consideration when developing a facility. Off-gassing and increased pellet temperatures start with the procurement of the wood and continue throughout the process if not properly managed.

DISCUSSION

Of the world's pellet production the majority of all pellets are produced using pine. The scientific name for Pine is ***Pinus*** and there are three main subgenera of the **Pinus; *Strobus, Ducampopinus*** and ***Pinus.*** For the purpose of this discussion I will be referring to the ***Pinus, subgenus Pinus***, which are the typical pines, yellow pines or hard pines. Mainly referred to as Southern Yellow Pine, it actually refers to thirteen different types of pines found throughout the south eastern United States to include; P. *Clausa*- Sand pine, P. *Echinata*- Shortleaf Pine, P. *Elliottii*- Slash Pine, P. *Taeda*- Loblolly Pine and P. *Glabra* – Spruce Pine. Each of the species above is a softwood but the wood is extremely harder than nearly all other hardwood species and this is particularly true in mature. In the production of pellets the resin content of pine is rather high which tends to contain higher energy values when burned. However, the resin which contains the energy is in the form of sugars and organic compounds, these compounds remain in the wood throughout the pellet production process and begin to break down during the storage and shipping process which leads us to the topic of this paper, **Procurement and Process Techniques for Controlling Off-Gassing and Pellet Temperatures.**

Throughout the pellet industry it is normal practice to procure the cheapest feedstock for the use of pelletizing without compromising pellet quality. In some areas and facilities tops, trimmings, and whole tree chips have been used to reduce overall operating costs since feedstock on average is the highest cost normally averaging 40%-50% of total cost for production. While it is known that the chemical composition of juvenile pinewood and mature pinewood is different little is done when procuring the wood to control the later effect of increasing pellet temps and off-gassing. In today's forestry market it is unlikely that it would be practical to procure wood that is mature since lumber mills are competing for this very same material. The use of pulp wood is the main source for pellet mills so another solution which is being tested currently is the aging or drying of the wood once it is cut. The rationale behind this idea is depending on the growing season and climate of the wood habitat, wood tends to have different moisture contents throughout the year. By allowing the wood to age in the yard prior to processing would allow the wood to begin the natural drying process and therefore lower drying temperatures would be needed in the process to achieve the normal 8%-9.5% moisture content of chips prior to pelletizing. Allowing the wood to dry naturally prior to being debarked and chipped would reduce chemical breakdown during chip pile storage as well. It is well known that spontaneous heating in piled wood chips and sawdust is caused by oxidation of unsaturated fatty acids and other extractives (Springer and Hajny 1970). Mills which bring feedstock into their facilities unload and chip it without storing it are putting on average chips with moisture contents from 40%-48% into their piles which will increase the chances of both spontaneous heating and chemical breakdown prior to processing.

Pellet mills throughout the world use different processes for the processing of feed stock once they chip their feedstock for instance; a mill located in the Southern United States produces pellets from Southern Yellow Pine chips that on average are ¾ inch square prior to entering a single pass dryer. Once it passes through the dryer it is placed into a silo until a hammer mill pulverizes the strand to a smaller size which is determined sometimes by the end user in contracts for particle distribution in co-fired boilers. Another mill located in the Midwestern United States is producing pellets from a northern hardwood recipe utilizing chips that on average are ½ inch square prior to entering a hammer mill which reduces the strand size prior to entering a triple pass drying system. After the dryer the strand then enters a second hammer mill to further reduce the strand size to meet the specs of the end users contract. Although there are different setups for facilities one must take into account many factors when processing feedstock for the use in making pellets such as; pellet end use whether it be residential, commercial, or industrial which is used for co-firing applications. Many industrial contracts state that the particle distribution must meet particular requirements due to the act of aspirating the pulverized wood into boilers just like coal.

With each process that the wood strand passes through the strand structure is altered. Kelley, Elder, Groom (2005) conducted research on the impact of processing conditions of chips. They showed that there are changes in the chemical composition as a function of refining actions. Drying temperatures have been strongly correlated to the volatile organic compounds (VOCs) emitted from stored pellets along with pellet temps. The major constituents of VOCs emitted from wood pellets are aldehydes some of which are known to be upper airway irritants (Hagstrom, 2008). The drying gas temperature is the only significant factor for aldehydes/ketone emissions. The higher dryer temperatures have been believed to remove more of the VOCs from the wood prior to pelletizing; however some believe the higher outlet temperatures actually open the cellular structure and once pelletized begin to emit more VOCs then what would have been emitted under lower temps. The reason for increased outlet temperatures is to reduce overall moisture content of the strand with increased throughputs depending on the system setup. The lower outlet temperatures normally result in reduced throughput of the system however the reduced heat will not emit as many VOCs and could possibly reduce VOCs and pellet temperatures in storage.

An analysis of VOCs emitted from fresh and stored Norway spruce and Scots pine during storage was conducted by Arshadi and Gref (2005). Unsaturated fatty acids were found to be the leading raw material of emitted VOCs. Aldehydes, such as pentanal and hexanal were found to be major constituents of the off gas but the amount and composition of emitted substances was affected by drying temperatures for the raw material and self heating of pellet stocks. Spruce and stored pine sawdust contained less fatty acid, and this should generate lower amounts of aldehydes. Arshadi and Gref concluded that it might be possible to reduce emissions from pellets in storage by optimizing the drying temperature and other process parameters such as aging of wood and raw material mixes.

Storage and the shipping of wood pellets have recently come under the spotlight since a fatal accident happened onboard a vessel in the Port of Helsingborg, Sweden, in November of 2006 while off loading wood pellets from British Columbia. In 2002 another fatality occurred and several others were injured under similar circumstances however it has not been reported in any scientific literature. A typical shipping vessel can carry 30,000 tons of pellets at a time and a typical port storage facility can store as much as 100,000 tons in a single open facility.

It is well known that all biomass gradually decomposes over time, chemically and biologically, slowly releasing toxic and oxygen depleting gases such as CO, CO_2, and CH_4. It has previously been reported that CO and other one-carbon compounds, such as methanol, formic acid and formaldehyde, are emitted from wood pellets during storage in warehouses (Svedberg et al., 2004). The authors also reported emissions of aldehydes, predominately hexanal and petanal, which they suggested were formed by a radical-induced oxidative degradation of natural lipids, particularly the polyunsaturated linoleic acid. The biochemical mechanism by which the one-carbon compounds were formed was not clear but again the oxidation of fatty acids and other components in the wood seemed likely. The oxidation processes occurred below room temperature but were accelerated by elevated temperature.

According to the following reversible exothermic reaction: $2CO + O_2 <> 2CO_2$, a high temperature will favour a high CO/CO_2 ratio. As the temperature rises, both CH_4 and CO_2 emissions increase according to Figures 1 and 2. At the same time, the CH_4/CO_2 ratio also increases, as shown in Figure 3. This indicates that CH_4 generation is favoured over CO_2 at a high temperature. In a conventional biomass composting system, CH_4 generation is usually associated with the anaerobic decomposition of biomass, while CO_2 likely is generated from the thermal oxidation of aerobic degradation.

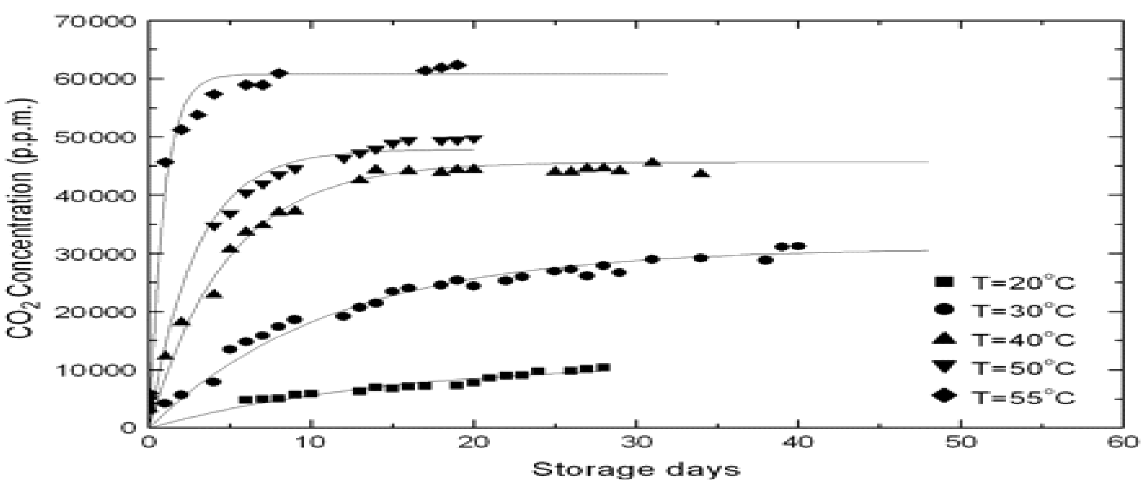

Fig. 1 CO_2 concentrations as a function of storage time at different storage temperatures

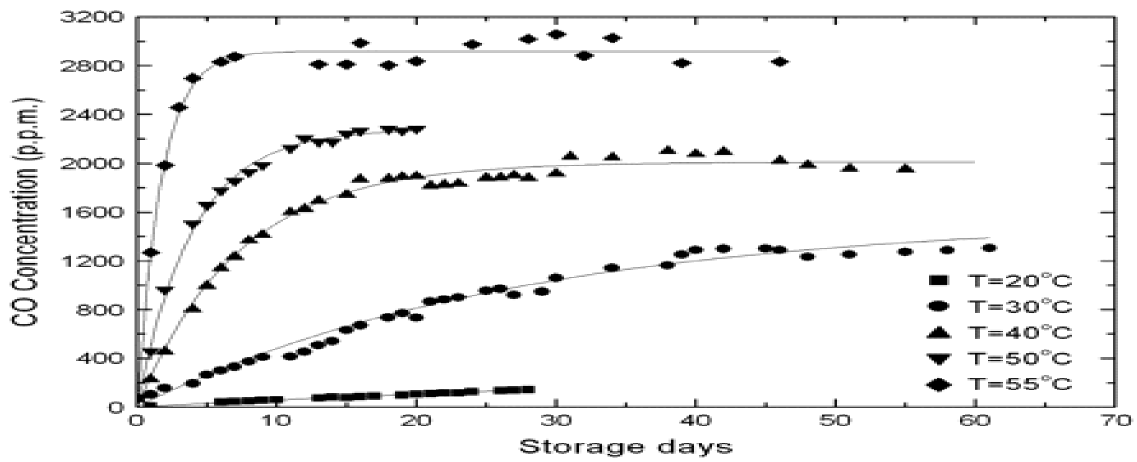

Fig. 2 CO concentrations as a function of storage time at different storage temperatures

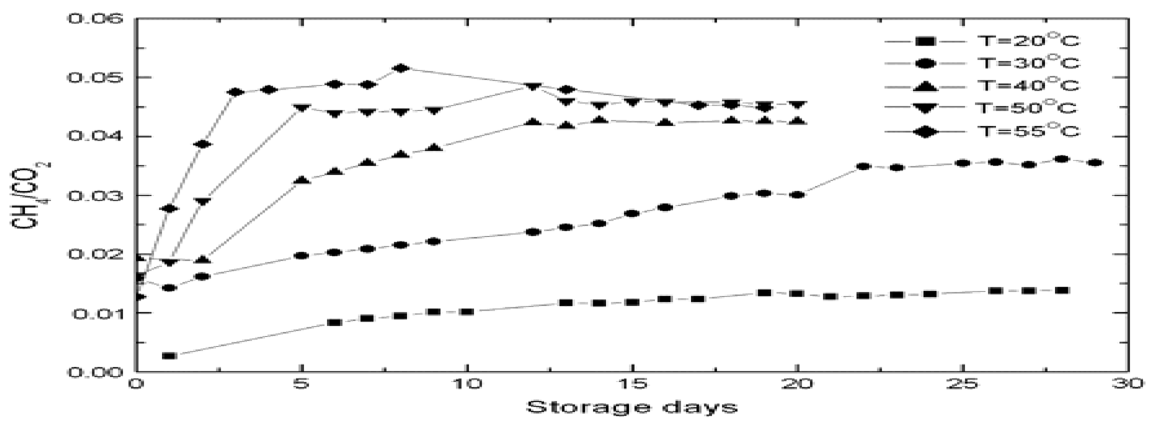

Fig. 3 CH_4/CO_2 molar concentration ratios as a function of storage time at different temperatures

The problem with pellets heating up or off-gassing is only noticed when shipped or stored in bulk at a facility while awaiting shipping. Many different types of storage facilities exist for the use of pellet storage whether it's a cylindrical silo like one used to store grains or a warehouse type in which pellets are loaded by conveyor then taken out by a loader. Since the beginning of mankind people have looked for ways to better preserve and store grains. Extensive research has been conducted in the storage of grains in different types of vessels in different climates however very little research has been conducted in the storage of wood pellets and what has been done has normally been in closed or sealed containers due to the cost and other limiting factors on testing. With all the research which has been conducted to date ambient temperature is the number one factor in regards to off-gassing and pellet temperatures. Nothing can be done to control ambient temperature so work must be done to control the temperature within the environment where the pellets are being stored. This can be done in several ways but must be first considered prior to the building of a facility and not an afterthought.

Aeration, also known as *active, mechanical, low-volume, or forced ventilation* can be defined as the forced movement of ambient air through grain bulk for improvement of storability (Calderon, 1972). Although the role of temperature has long been recognized as an important regulator of biological processes, manipulation of temperature by aeration techniques was first brought into focus in the 1950's. The objectives of aeration on pellets can be best described as:

- Cooling of the pellets
- Equalizing temperature throughout the pellets
- Preventing biological heating in damp pellets
- Circulating of off-gasses
- Removing odours created by off-gasses

Aeration of pellets will also help prevent moisture migration and head-space water compensating humid climates. Rates of chemical deterioration such as oxidation of fats during storage are very slow and sometimes insignificant at low temperatures. The rate of chemical reaction taking place is significantly increased with each 10^0C in temperature. Therefore maintaining the temperature in the pellets is essential.

Ambient air temperature, solar radiation, atmospheric weather changes that result in major barometric pressure fluctuations and storage structure parameters affect the transfer of heat within the stored grain. Different structures should be evaluated in different climates such as in climates of high latitudes, south walls in the northern hemisphere and north walls in the southern hemisphere intercept most of the solar radiation. Therefore, rectangular bins should be placed with their longer axes running north to south to help keep the pellets cooler. Depending on the thermal absorptivity and emissivity of the structural material and the surface temperature, solar radiation may result in heat gain or loss from the stored pellets. From the aspect of grain bin wall temperatures and grain warming from solar radiation, regardless of bin size and geographic location, insulated galvanized steel is the worst material and galvanized steel is the second worst material to use for bin walls (Yaciuk et al.1975).

CONCLUSION

The easiest and most economical way to control pellet temperatures and off-gassing in storage facilities may to control it within the storage facility itself. The procurement of mature wood is not feasible for the sake of producing pellets. Lowering dryer outlet temps therefore reducing the opening of the porous structure and not increasing the surface of the material simultaneously is not practical due to the fact facilities are expensive to operate and the more throughput the higher the yields which increase productivity and profit margins. With proper planning pellets can be stored in a warehouse without risk of off-gassing and spontaneous heating. The initial upfront capital of building a storage facility which has aeration will be significantly cheaper in the long run than having union port stevedore's constantly moving product to disperse heat within piles like some wood chip management practices. The information contained within this paper has shown temperature is the main factor in the process, by managing temperature we manage both off-gassing and pellet temperatures can be managed. Off-gassing and heating of pellets is a natural process which we cannot stop, but we can control to ensure staff safety and pellet quality.

REFERENCES

Svedberg U, Hogberg H, Hogberg J. (2003) Emission of Hexanal and Carbon Monoxide from Storage of Wood Pellets, a Potential Occupational and Domestic Health Hazard. British Occupational Hygiene Society; Vol 48, No 4, pp 339-349.

Kuang X, Shankar T, Bi X, Sokhansanj S, Melin S. (2008) Characterization and Kinetics Study of Off-Gas Emissions from Stored Wood Pellets. British Occupational Hygiene Society; Vol.52, No 8, pp 675-683.

Kelley S, Elder T, Groom L. (2003) Changes in the Chemical Composition and Spectroscopy of Loblolly Pine Medium Density Fiberboard Furnish as a Function of Age and Refining Pressure. Society of Wood Science and Technology; Vol. 37, Number 1.

Arshadi M, Geladi P, Gref R, Fjallstrom P. (2009) Emission of Volatile Aldehydes and Ketones from Wood Pellets under Controlled Conditions. British Occupational Hygiene Society; Vol. 53, No. 8, pp 797-805

Shlomo N, Noyes R. (2002) The Mechanics and Physics of Modern Grain Aeration Management. CRC Press