CHEESA: Chemical Engineering Research Articles
ISSN **2614-8757 (Print)**, ISSN **2615-2347 (Online)**
Available online at: http://e-journal.unipma.ac.id/index.php/cheesa

Research Article

The Effect of H-Factor on Kappa Number and Viscosity in Continuous Digester

Pengaruh H-Factor terhadap Kappa Number dan Viscosity pada Continuous Digester

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Article History
Received: 14th February 2023; Revised: 05th May 2023; Accepted: 06th May 2023; Available online: 15th June 2023; Published Regularly: June 2023

doi: 10.25273/cheesa.v6i1.15681.26-33

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Abstract

One of the most important steps in pulping is the cooking process, which serves to separate the cellulose and hemicellulose from lignin and other by-products. During the cooking process in the digester, various factors must be considered to create high-quality pulp. Among these factors, the H-Factor plays a significant role due to its impact on the kappa number and viscosity in the pulping process. A high H-Factor can also damage the strength of the pulp. Therefore, this research aims to investigate the effect of the H-Factor and active alkali on pulp yield and quality. The active alkali used was in line with the desired production objectives, as insufficient levels of active alkali can lead to a low yield of pulp. Meanwhile, pulp quality standards in the Pulp and Paper Industry included kappa number of 12-18 in the digester process, an approximate viscosity of 23 mPa.s, and the selection of H-Factor based on the desired production target.

Keywords: active alkali; cooking process; H-Factor; kappa number; viscosity

Abstrak

Salah satu langkah terpenting dalam proses pulping adalah proses pemasakan. Tujuan dari proses pemasakan ini adalah untuk memisahkan selulosa dan hemiselulosa dari lignin dan produk sampingan lainnya. Dalam proses pemasakan pada digester, banyak faktor yang harus diperhatikan untuk menciptakan kualitas pulp yang baik, yaitu H-Factor, karena sangat mempengaruhi bilangan kappa dan viskositas dalam proses pulping. H-Factor yang tinggi akan merusak kekuatan pulp. Penggunaan alkali aktif harus sesuai dengan tujuan produksi yang ingin dicapai. Ketika alkali aktif ini terlalu rendah maka yield pulp akan rendah. Kualitas pulp pada industri Pulp and Paper meliputi beberapa standar antara lain bilangan kappa adalah 12-18 pada proses digester, viskositas sekitar 23 mPa.s, dan H-Factor yang digunakan bergantung pada target produksi.
Kata kunci: *alkali aktif; bilangan kappa; H-Factor; proses pemasakan; viskositas*

1. Introduction

A major part of the pulp production process is the digester [1]. The digester has several parameters such as temperature and time, which are expressed in H-Factor during the cooking process. This H-Factor has a significant effect on pulp quality, namely the kappa number, and viscosity. The kappa number is used to express the amount of lignin remaining in the pulp and the viscosity determines the strength of the pulp produced [2]. In this unit, temperature and residence time during cooking are among the parameters that determine pulp quality as well as the amount of time and chemicals consumed.

In the pulp production process, one important factor to be considered is the relationship between time and temperature, which is expressed in the H-Factor [3]. When the H-Factor is excessively high, it can cause the chips to overcook, resulting in the reduction of the lignin content due to maximum degradation. This will bereave more cellulose fibers due to the degradation process that causes a decrease in pulp quality. However, a low H-Factor has a negative impact, as it indicates that the wood chips are not cooked well and need to be reprocessed, resulting in increased consumption of time and chemicals.

Several parameters including the H-Factor need to be considered to obtain high-quality pulp [4]. The H-Factor is one of the cooking variables that should be considered when processing wood chips in the digester unit due to its relationship with the strength of the pulp (viscosity) and the amount of lignin remaining in the chips (kappa number). Therefore, this research aims to examine the kappa number and viscosity values of the pulp obtained from the blow tank with varying H-Factor.

2. Research Methods

Several steps were taken to determine the effect of the H-Factor on the kappa number and viscosity of pulp in continuous digesters. These included literature research, data collecting, data processing, calculation of white liquor composition, and analysis of the effect of the H-Factor on kappa number and viscosity. The representation of the research steps is shown in Figure 1.

The required data for this research were obtained from observations made at the Digital Control System (DCS) in the Pulp and Paper industry. The data were collected based on the production results from May to July 2022 at PT. Tanjung Enim Lestari Industry Pulp and Paper, Tanjung Enim, South Sumatera.

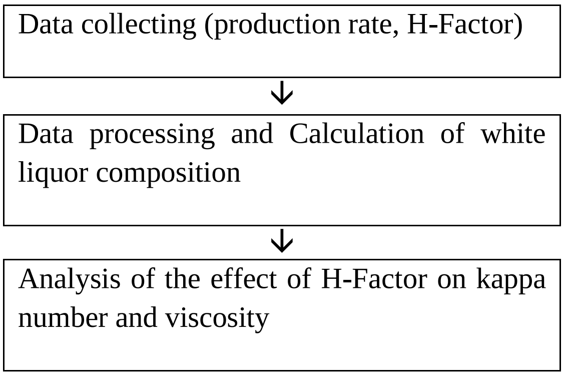


Figure 1. Flow chart of research

3. Result and Discussion

The two factors that influence chip maturity in solvents are time and temperature during cooking, which significantly affect pulp quality. Moreover, the H-factor represented the relationship between cooking time and temperature. This H-Factor aims to achieve a pulp viscosity standard of 23 mPa.s and a kappa number ranging from 12 to 18. These two parameters must meet the standards because when the viscosity is too high, it will create a pulp that is prone to breakage. For example, excessively high kappa numbers cause yellow spots in the pulp produced, while lower values result in the easy breakdown of cellulose fibers. [5]. In a Pulp and Paper Industry, the primary objective is to ensure pulp quality and meet production targets. To achieve this, the pulp digester unit must optimize the production rate that meets the kappa number with minimum chemical and energy inputs through the arrangement of the H-Factor [6].

3.1 Effect of H-Factor on Production Rate

In this research, the H-Factor used in the digester unit was determined by the production rate. It ensured the attainment of effective temperature and residence time during chip cooking and produced optimal pulp quality. Table 1 provided the data on production levels with their respective H-Factors.

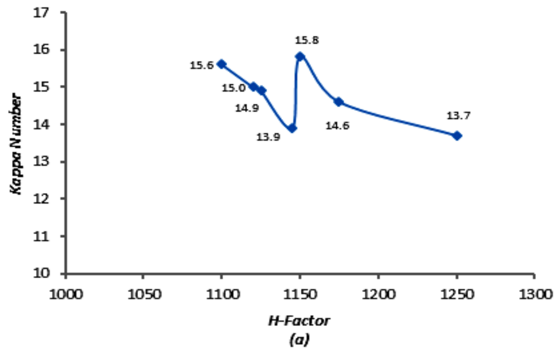
Table 1 showed the best data for each production target based on the quality parameters of viscosity, brightness, and kappa number, which were close to the standardized values. The higher the production rate, the greater the H-Factor used and the more optimal the pulp quality. Based on the observation data in Table 1, the best pulp production was obtained at the target of 1500 ADT/d with an H-Factor of 1175. This resulted in a kappa number of 15.8, a viscosity of 20.5 mPa.s, and a brightness value of 29.5% ISO. These values fulfilled the required pulp quality standards in the Pulp and Paper industry. Moreover, the use of a higher or optimal H-Factor used caused a greater degradation of lignin, yielding a higher brightness value, with optimum kappa number, and viscosity [7].

The use of a low H-Factor in high production resulted in a non-optimal kappa number and pulp viscosity which required higher active alkali consumption and production cost [7].

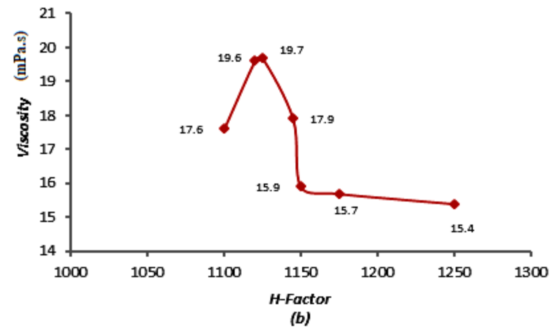
3.2 Effect of H-Factor on Kappa Number and Viscosity

The H-Factor used in the cooking stage played crucial in determining the value of the kappa number and viscosity of the pulp. Based on previous research, a higher or optimized H-Factor used will result in greater lignin degradation, indicating more effective temperature and residence time during chip cooking [8].

Figures 2 (a) and (b) showed the contrasting relationship between H-Factor and both the kappa number and viscosity. The results revealed that as the H-Factor increased, there was a corresponding decrease in the value of kappa number and viscosity, indicating a significant degradation in lignin. Kappa numbers standard obtained ranged from 12 to 18 and no statistically significant differences were observed.



(a)



(b)

Figure 2. (a) Relationship between H-Factor and Kappa Number, (b) Relationship between H-Factor and Viscosity at a Production rate of 1200 ADT/d

Table 1. H-Factor at each production level

Date	Production Rate (ADT/d)	H-Factor	Viscosity (mPa.s)	Kappa Number	Brightness (%ISO)
09/05/22	1200	1125	19.7	14.9	27.7
03/07/22	1300	1145	19.4	15.7	29.4
02/06/22	1400	1175	20.4	15.8	29.4
04/05/22	1500	1175	20.5	15.8	29.5
26/06/22	1600	1150	19.1	15.0	29.0

The kappa number increased at an H-Factor of 1150 and decreased at the highest H-Factor. These results showed that H-Factor served as a useful tool to predict and control the rate of delignification, even when employing different combinations of pulping time and temperature. The viscosity increased with H-Factor due to the removal of hemicellulose and the weakening of cellulose in the extractive step. However, the viscosity decreased due to cooking treatments [9].

Figures 3 (a) and (b) showed the inversely proportional relationship between H-Factor and both the kappa number, and viscosity. Based on the results, the higher the H-Factor used, the lower the value of the kappa number. This indicated that more lignin was degraded during the cooking process.

The kappa number was influenced by the cooking liquid ratio and control parameters such as H-Factor or increased cooking time. When using a low active alkali with a long cooking time or vice versa, the factor was influenced by the moisture content of the wood.

In this production, a decrease in viscosity was observed at the H-Factor of 1600. The initial increase in viscosity was due to a decrease in hemicellulose content or a high degree of polymerization (DP) of the pulp in the remaining cellulose fraction.

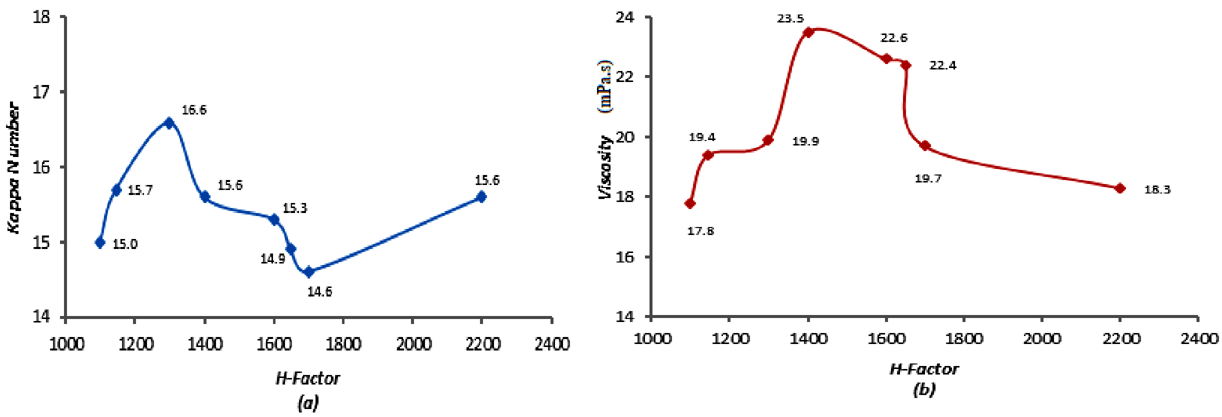


Figure 3. (a) Relationship between H-Factor and Kappa Number, (b) Relationship between H-Factor and Viscosity at a Production rate of 1300 ADT/d

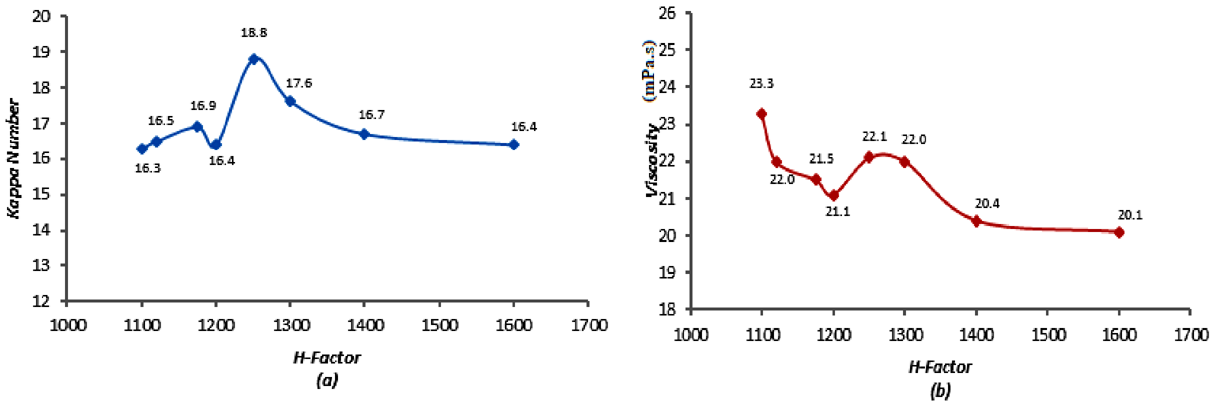


Figure 4. (a) Relationship of H-Factor and Kappa Number, (b) Relationship of H-Factor and Viscosity at a Production rate of 1400 ADT/d

The maximum viscosity with extraction severity indicated that the use of a high H-Factor resulted in fiber breakage due to increased accessibility of cooking liquor to crystalline cellulose. Therefore, to maintain fiber strength and crystallinity at this level of extraction, the cooking liquor should be weaker [9].

Figures 4 (a) and (b) showed that the relationship between H-Factor and both kappa number and viscosity was inversely proportional. This indicated that the higher the H-Factor used, the lower the value of the kappa number. However, in the H-Factor of 1250, the kappa number had increased slightly. This was not in line with the theory, where a higher H-Factor caused a decrease in the kappa number. For the H-Factor of 1250 that contrast with theory, high kappa numbers occurred due to the low active alkali charge used in the cooking process [9], as indicated by the large number of rejects produced. The low active alkali charge made the kappa number still significantly high. The use of excessively low active alkali charge also produced more rejects of undesired pulp [10]. This rejection was caused by uncooked wood chips in the digester because the incomplete delignification process decreased pulp quality. Therefore, the use of active alkali loading should be considered to obtain the best pulp quality [9]. In this research, the viscosity value increased at H-Factor 1250.

Most of the increase in viscosity increase can be traced to the removal of hemicellulose and high cellulose content. The removal of the hemicellulose increased the crystallinity index of pulp fibers in the softwood fibers [9].

Figure 5 (a) showed that there was no continuity between the theory of the H-Factor and the kappa number. Furthermore, the relationship between H-Factor and kappa number was directly proportional.

Pascoal, et al stated that variations in time during cooking with a constant temperature affected the value of the kappa number. This was because a longer cooking time caused a reduction in the value of the kappa number and vice versa [11]. The cooking time was also directly proportional to H-Factor. Therefore, it can be concluded that the increase in kappa number in Figure 5 (a) was caused by high cooking temperature with low time. A decrease in kappa value was in line with the increasing H-Factor and cooking temperature, leading to more degradation of lignin.

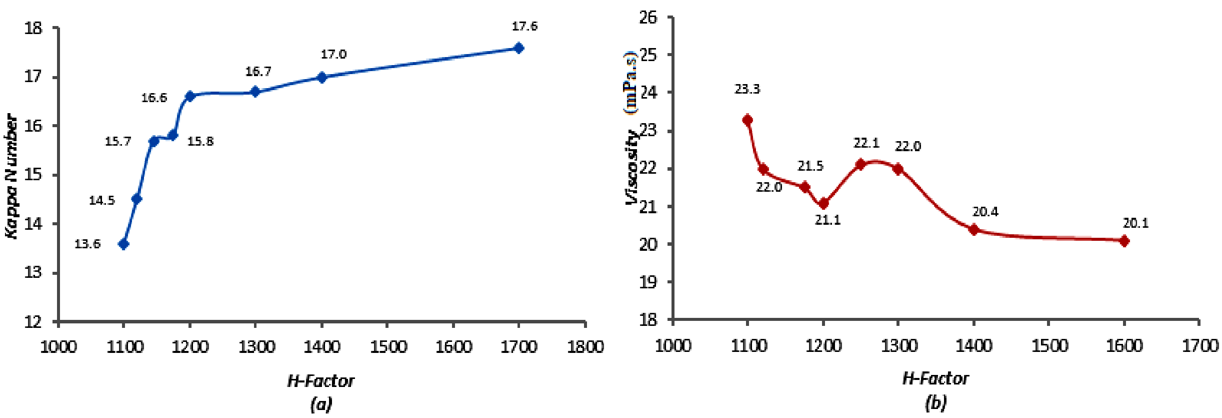


Figure 5. (a) Relationship of H-Factor and Kappa Number, (b) Relationship of H-Factor and Viscosity at a Production rate of 1500 ADT/d

The main objective of cooking is to reduce the lignin content, as measured by the kappa number as a standard. An increase in active alkali content leads to a decrease in pulp yield. Therefore, the higher the active alkali content used during the cooking process, the lower the pulp yield. Every 1% increase in active alkali content will also reduce pulp yield by 0.15% due to the high degree of delignification [12].

The relationship between H-Factor and viscosity shown in Figure 5 (b) was inversely proportional. The results showed that the higher the H-Factor used, the lower the viscosity value achieved. This result was in line with related research data, where the H-Factor value was inversely proportional to the viscosity value [7]. However, at lower H-Factor variations of 1100, 1120, and 1145 there was a high viscosity value. Viscosity was a function of cellulose fiber degradation in the pulping process (Tappi T-230). In this context, temperature ranging from 150 to 170°C was the main driving force for degrading the cellulose pulp structure by the associated viscosity decrease. The viscosity increased with H-Factor due to the removal of hemicellulose and short-chain cellulose in the extractive step, which further decreased as a result of more severe cooking treatments.

The high viscosity at low white liquor ratios can be attributed to good interfiber connections. Meanwhile, a limited amount of white liquor weakened the cellulose bond. [13]. The high pulp viscosity was expected to improve pulp quality, pulp strength, tensile strength, and ease of treatment.

Figures 6 (a) and (b) showed that the relationship between H-Factor and kappa number was inversely proportional. This indicated that the higher the H-Factor used, the lower the kappa number. Similarly, previous research stated that the H-Factor value was inversely proportional to the viscosity value and kappa number [7].

The H-Factor in the cooking process affected the kappa number and viscosity of the pulp. Based on the data, a higher production rate led to an increase in the H-factor used. However, excessively high temperatures and cooking time can damage cellulose, leading to low pulp yield [14]. To ensure the desired chip maturity, the relationship between temperature and time must be maintained, as shown in the H-Factor. This balance is necessary to achieve the desired kappa number and pulp viscosity.

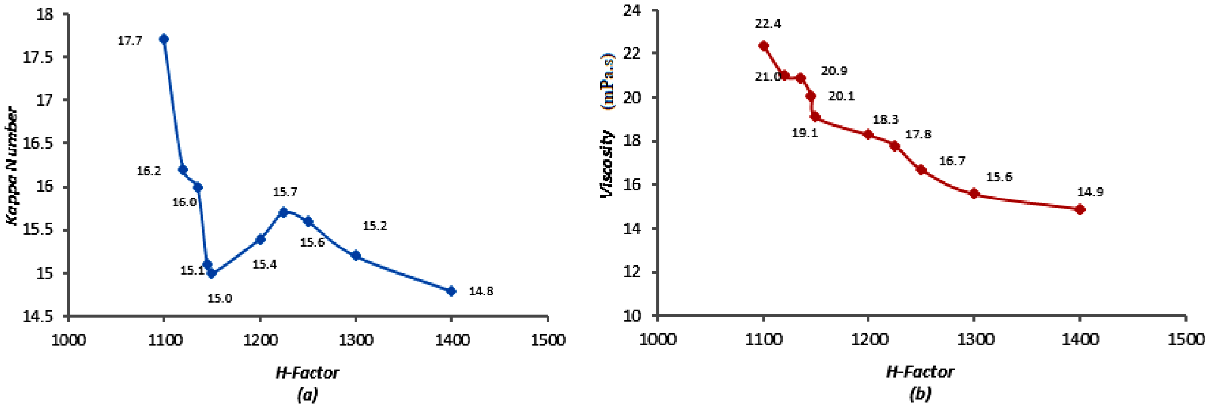


Figure 6. (a) Relationship of H-Factor and Kappa Number, (b) Relationship of H-Factor and Viscosity at a Production rate of 1600 ADT/d

The H-Factor is a variable that needs to be controlled to obtain the kappa number of the pulp produced. When the kappa number value exceeds the standardization, it can increase the H-Factor and vice versa [15].

In a cooking process system (digestion), many parameters must be considered to obtain the best results, with temperatures ranging from 150 to 170^{o}C. A good quality pulp with a high white liquor content can be obtained by controlling the H-Factor with a short cooking time. However, this approach requires a high price for chemicals. The H-Factor is used as a variation of time and temperature to describe the cooking conditions and optimize the process without any wasted energy. The equal distribution of the white liquor throughout the cooking section enables the chips to cook at the appropriate temperature and time.

4. Conclusion

The best pulp production at the target of 1500 Adt/d was obtained at an H-Factor value of 1175 with a kappa number parameter of 15.8, a viscosity of 20.5 mpas, and a brightness value of 29.5% ISO. This indicated that higher production levels led to a greater H-Factor, thereby producing the optimal pulp quality. The results met the TAPPI standard such as 1-100 of kappa number (TAPPI/ANSI T 236 om-13) and viscosity of 7 – 27 mPa.s (TAPPI T 230 om-08). The H-Factor was also influenced by the active alkali charge of white liquor. The relationship between H-Factor and kappa number and viscosity was inversely proportional. This was shown by a decrease in viscosity and kappa number due to a higher H-Factor value. The H-Factor was used as a time adjustment at various cooking temperatures and condition estimation, in case of deviations from the operating standards.

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