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## Design and Fabrication of Modified Condensers for Optimum Extraction of Dyes

By

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### ABSTRACT

Condenser is a device designed to separate one or more components of a vapour mixture by reducing a gas or vapour to its liquid form. This study was undertaken with a view of investigating the design and performance analysis of outer jacket Allihn and Graham glass condensers on extraction of natural dye. AutoCAD design tool was used in designing Allihn and Graham condensers, varying the number of bulbs from one to ten (1-10) on the outer jacket. Allihn and Graham are commonly used heat exchangers (Apparatus) in teaching and research laboratories. They are used in reflux reactions, distillation of liquid mixtures and extraction of important organic compounds. Forty assorted condensers were designed with different number of bulbs on their outer jacket in order to increase the surface area. Twenty (20) assorted pieces of each type "As" and "Bs" of these modified structures of Allihn and Graham condensing models were fabricated. The performance of these condensers was evaluated using extraction procedures involving leaves of lawsonia inermis (natural dye) with acetone as solvent. The result showed that the highest yield of crude extracts was (43.49%) for condensing models with 7 bulbs in types "As" Graham and the type "Bs" model with 41.36% yield on extraction respectively. Allihn type "Bs" model with 7 bulbs also gave a yield of 39.99% while the Allihn "As" model was 39.95%. This implies that condensing models with 7 bulbs on outer jacket of Graham are more efficient for extraction and are better than the Allihn which used in refluxes reactions.

Key words: Condensers and Extraction of dyes

### INTRODUCTION

Condenser is a device designed to separate one or more components of a vapour mixture by reducing a gas or vapour to its liquid form. The design and operation of a condenser are greatly affected by the number of chemical and physical properties of the contaminants, the moisture and particulate content of the flare gas, gas flow rates, condenser temperature and the required removal efficiency (Zahural, 2011; Jekada *et al*, 2017<sup>A</sup>). The simplest form of condenser requires that the designer determines the condensation temperature, select a coolant and the size of condenser in the most complex form, chemical engineering principles for gas dehumidification are required (Kolmetz, 2011). Condensers are of good help, by regulating temperatures and generally making our lives easier i.e the petroleum and chemical industries employ condensers for the condensation of hydrocarbons, the same goes in automotive applications which the engine bay contains the air conditioning unit which consists of compressor, condenser and other parts

that regulate cabin temperature and humidity (Alexander, 2016). AutoCAD design tool was used in designing Allihn and Graham condensers, varying the number of bulbs from one to ten (1-10) on the outer jacket. The following specifications were kept constant: outer bulbs size of diameter  $\theta$  48 mm, distance from bulb to bulb length of 18 mm inner tube  $\theta$  09/679 mm, outer tube length  $\theta$  40/720 mm, bulbs and tubes of  $\theta$  26/60 mm, outlets and inlets  $\theta$  09/1.5 mm and the length of quick fit 84 mm with the exception of Graham condensing models which inner tubes are coils. For types "As" Allihn and Graham condensers, the outlet and inlet tubes were joined to their jackets while for the types "Bs" Allihn and Graham models, the outlet and the inlet tubes were joined directly to their inner tubes. Twenty (20) assorted pieces of each type "As" and "Bs" of these modified structures of Allihn and Graham condensing models were fabricated. The performances of these condensers were determined using extraction procedures involving the leaves of *lawsonia inermis* (natural dye) with acetone as solvent.

Natural dyes are dyes or colorants derived from plants, invertebrates or minerals; the majority of natural dye is vegetable dye from plant sources, roots; berries bark leaves and woods; and other organic sources such as fungi and lichens. Natural dyes are friendly and convenient to use. They are familiar sources that can spark creative ideas and widen one's view of the world in experimenting with them. Colours can be coaxed from all kinds of natural sources. It is important to note that all natural dye recipes are safe and non-toxic (Tahir *et al.*, 2005; Aung and Win, 2008; Altioek *et al.*, 2008; Adeel *et al.*, 2009; Syed *et al.*, 2015).

Dyes are classified based on their structure, source, and method of application, colour, etc. Briefly described below are two types of classification of dyes based on chemical structures *Indigoid dyes*: This is perhaps the most important natural dye, obtained from *Indigofera tinctoria*. *Anthraquinone dyes*: Some of the most important red dyes obtained from either plants or insects are based on the anthraquinone structure. These dyes are characterised by their form complexes with metal salts and the resultant metal-complex dyes have good wash fastness (Tahir *et al.*, 2005; Altioek *et al.*, 2008; Adeel *et al.*, 2009).

## METHODOLOGY

### *Fabrication of Allihn Condenser*

A required length of glass tube was heated until it became soft enough to gather, it was then placed in a bulb mould and blown to fill the mould while synchronizing for uniformity. Allihn condenser with five bulbs was moulded first, five bulbs were the maximum number of bulbs the mould can accommodate so the remaining number was blown separately, joined, fire polished and flame annealed. The glass bulbs were wrapped with cardboard and inserted into the outer jacket using a glass rod to hold it centrally. The same basic operational principles were employed in the production of the blown outer jackets bulbs. The blown number of bulbs that were introduced on the outer jacket was centrally integrated with equal distance starting from the first bulb.

### *Fabrication of Graham condenser*

1219.2 mm length of 6 mm diameter glass tubing and mandrel covered with ceramic paper are essential for the coil winding. The mandrel was preheated slightly and the hook was bent on

the end of the 6 mm tube. The hook was knit to the rod attachment on the mandrel. The 6 mm glass tubing was heated in a large bushy flame until it reached the working temperature to be bend and coiled while the spacing was carefully observed. The hook end of the coil was broken away from the mandrel as soon as the coil and mandrel were cooled. The glass coil was removed from the mandrel while synchronizing the rotation and running them under cool tap water. The ends of the coil were cut, fire polished and flame annealed.

The blown mould was used to produce the bulbs at the outer jacket as it was done in Allihn condenser and flame annealed. The glass coil was wrapped with cardboard and inserted into the outer jacket using a glass rod to hold it centrally joined together and flame annealed. The surface area was created to increase the cooling rate. The in-let/outlets were created using  $\varnothing 8/1.5$  mm glass tube which were also at both ends and flame annealed too.



**Plate I:** Samples of type “As” Allihn Glass Condensers (conventional)



**Plate II:** Samples of type “Bs” Allihn Glass Condensers (unconventional)



Plate III: Samples of type "As" Graham Condenser (conventional)



Plate IV: Samples of type "Bs" Graham Condenser (unconventional)

### ***Extraction of Natural dye using Modified Condensers***

The modified Allihn and Graham condensers were used to carry out solvent extraction of *Lawsonia inermis* plant leaves according to Soxhlet extraction method EPA 2701C (Luque de Castro and Garcia, 2000). The leaves were washed with water to removed dirt and other adhering materials, dried in a tray drier at 40°C for 48 hours and finely grounded with the help of a grinding machine. 20 grams of the ground powder *Lawsonia inermis* was wrapped in thimble, placed inside 500 mL soxhlet extractor. The four soxhlet extractors were connected with four 500 mL round bottom flasks which served as the reservoir for the concentration. 300 mL of the solvent (acetone) was poured through the soxhlet opening to allow the samples and the solvent to mix in the extracting chambers. The four sets of the condensers were connected vertically under reflux position and heated at 56°C concurrently, the temperature was allowed to gradually build up to boiling point and the extraction time of 6 hours was set for all the samples.

Acetone was used as the organic solvent because it has been established and known to be provided effective tracer for fluid flow experiment and tap water as the coolant flowed through

the hose which was connected from the water source to the inlet tube; and another hose was connected in series to the outlet tube for the four extraction set-up. Heat was supplied from four electric heating mantles and regulated at a constant temperature of 56°C to the boiling point of the organic solvent as shown in plate VI. The extract continued to siphon into the reservoirs for six hours till the solvent in the Soxhlet extractor was almost colourless from the initial green colour.

The flasks were rinsed properly with fresh acetone and the crude extract washed was then transferred from the sample bottles placed on top of water bath set at a temperature 50 °C below the boiling point of the solvent. This was allowed to evaporate the remaining solvent leaving only the crude extract which was weighed using analytical balance.

## RESULTS

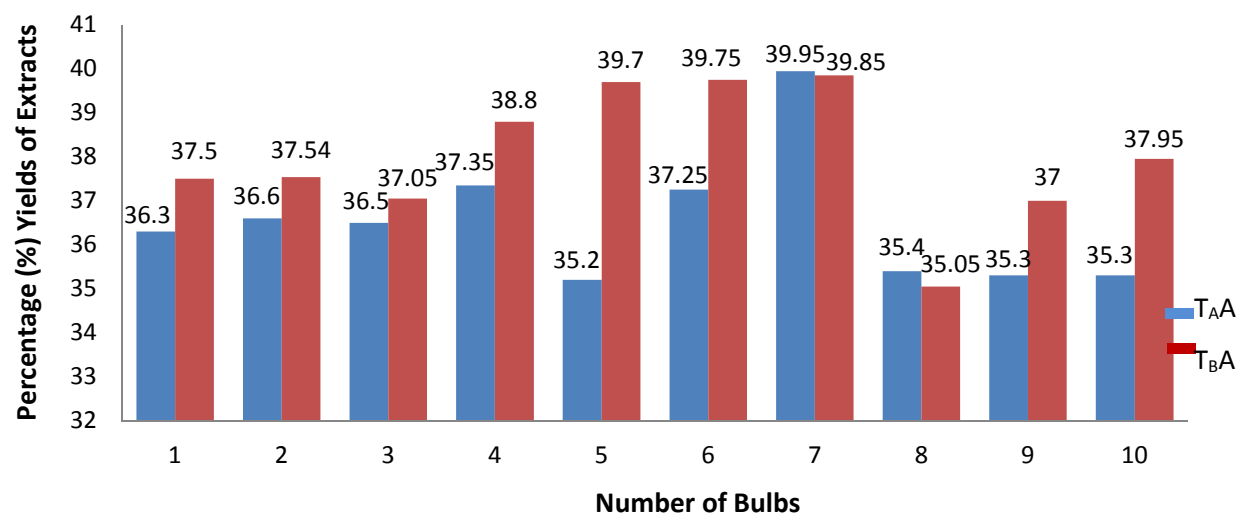


Figure 1.1: Percentage Yields of Extracts Types As and Bs Allihn Condensers

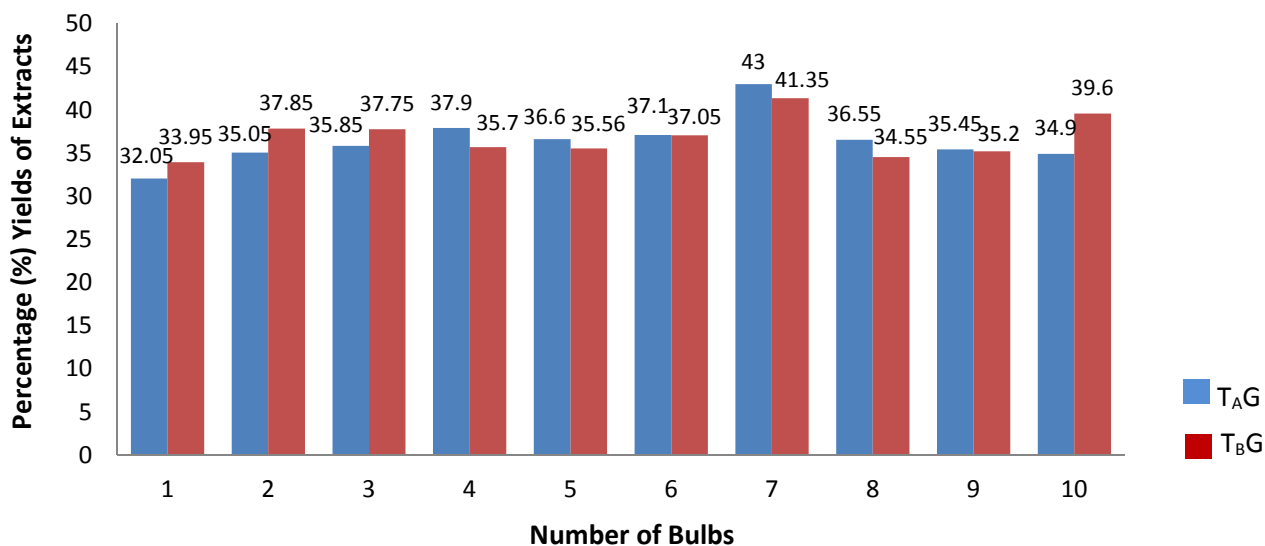
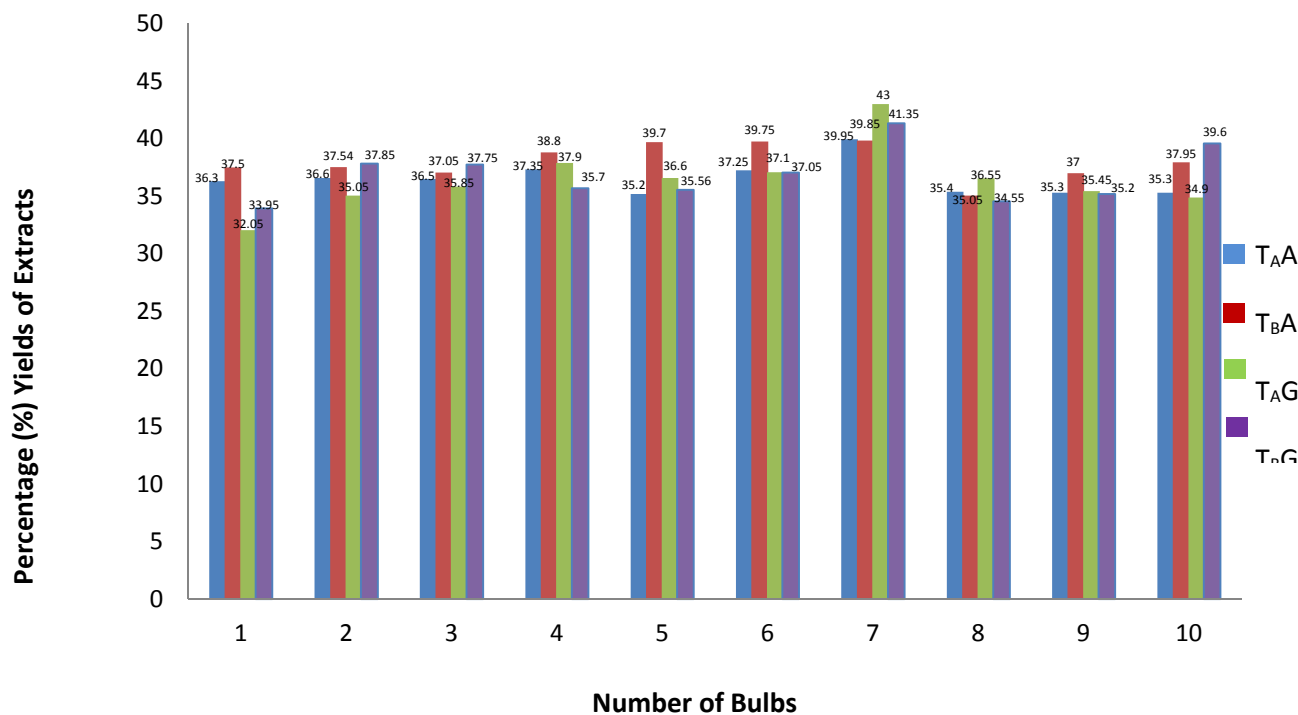


Figure 1.2: Percentage Yields of Extracts Types As and Bs Graham Condensers



**Figure 1.3:** Percentage Yields of Extracts Types As and Bs Allihn and Graham Condensers

## DISCUSSION

Figure 4.1 types “As” Allihn models show percentage yield of the extracts at different number of bulbs from 1-10. The type “As” Allihn condenser model with 7 bulbs gave the highest yields of 39.95%, followed by the model with 4 bulbs (37.34%). While condensing models 9 and 10 bulbs gave the lowest yield of 35.20% each. Allihn type “Bs” condensing model with 7, 6 and 5 bulb gave the yield of 39.85%, 39.75% and 39.70% respectively. The least yield of 35.05% was observed in the condensing model with 8 bulbs. The overall performance of both types “As” and “Bs” Allihn condensers revealed clearly that there was significant increase in the percentage yields of crude extract in type “Bs” Allihn than those in type “As” Allihn condensers. This is probably due to the coolant flowing through the inner tube as a result of the improvement in the design modification which increased the effectiveness of the cooling system as reported by Jensen (2006); Keyser (2014).

Figure 4.2 Graham condensing models, types “As” with 7 bulbs gave 43.48% yields of extract followed by the condensing model with 4 bulbs 37.90%, while the least percentage of crude extract with 32.05% was observed in condensing model with 1 bulb. This behavior observed in condensing model with one bulb might have resulted from the prolonged contact with the coolant because of the coiling nature of the Graham condenser which made the cooling take a longer period of time in agreement with Jensen (2006). In Graham type “Bs” condenser with 7 bulbs the highest percentage of extracts 41.35% was observed followed by the condensing model with 10 bulbs yield of 39.60% and the least yield of crude extracts was obtained with condensing model with one bulb 33.95% which is in conformity with the results obtained in types “As” Allihn condensers with one bulb.

Graham types “As” and “Bs” show that types “Bs” and “As” Graham condensing models yielded more of the crude extracts than the types “As” and “Bs” Allihn because of the design modification which provided more surface area for cooling as reported by Delmar (2012). The design modification of Graham condensing models by introduction of bulbs at the outer jacket increased the surface area which in turn increased the cooling, so the more the cooling the more the yield of extracts (Jekada *et al*, 2017<sup>B</sup>). However, this finding was observed to be in disagreement with the finding of Jensen (2006); Kotz (2008) which state that Graham condensing models cannot be used in refluxes due to the narrow path of the inner coil. Figure 4.3 shows that design modification has a greater effect on the overall performance of these models. The optimum extraction was found in the condensing models with 7 bulbs with the highest crude extracts of 39.95%, 39.98, 43.48% and 41.35% respectively for both Allihn and Graham Types “As” and “Bs” condenser. The performance analysis of these condensing models further showed that the percentage yields is not a direct function of the number of bulbs introduced but the effectiveness of the cooling system. Based on materials selection, further fabrication of these condensing models with bulbs above or below 7 will amount to a waste of production cost, materials and time because there will be little or no significant increase of the crude extracts (Gonah, 2014).

## CONCLUSION

The efficiency of these condensers was established using extraction of natural dyes from *lawsonia inermis* plant leaves. The highest yield was observed to be in condensing models with 7 bulbs in both types “As” Graham with 43.00% followed by type “Bs” model with 41.35% yield on extraction. Allihn type “Bs” model with 7 bulbs also had a yield of 39.99% while the Allihn “As” model was 39.95%. Assorted condensing models with 7 bulbs on the outer jacket are generally more suitable and efficient for extraction, especially the Graham condensing models types “As” and “Bs”.

## REFERENCES

- Alexander, M. (2016). How a Condenser Works and Applications? Online Help Guide. Retrieved February 2, 2015, from <http://gethelpoline.org/howacondenserwork>
- Altiok, E, Baycin, D, Bayrakar, O; Uku, S. (2008). Isolation of Polyphenols from the Extract of Olive leaves (*Olea Europea L*) by Adsorption on Silk Fibroin-sep. *Purif. Technol* 62 (Z). Pp342-348.
- Arun, K. P. and Yogamoorthi, A. (2014). Isolation, Application and Biochemical Characterization of Colour Component from *Tecoma Stans*: A New Cost Effective and Eco-friendly Source of Natural Dye. *International Journal of Natural Products Research*. 4 (1): Pp 9-11.
- Delmar, J. (2012). Experimental Chemistry – Choosing the Right Condenser- Chemistry <https://Chemistry.Stackexchange.com/questions/608/choosing-the-right-condenser/> retrieved 6/6/2012. Pp1-4
- Gonah, C. M. (2014). Optimization of Glass Condensers by Solid Modelling. Unpublished Ph.D. Dissertation Submitted in Partial Fulfillment of for the Award of Doctor of Philosophy. Department of Industrial Design, Ahmadu Bello University, Zaria.

- Jensen, W. B. (2006). The Origin of the Liebig Condenser. *Journal of Chemical Education* (83), p23 <http://jchemed.chem.wise.edu/journal/issues/2006/jan/abs23.html>
- Jekada, J. Z., Gonah, C. M., Garkida A. D., Ladan, Z. (2017<sup>A</sup>). Design Modification of Assorted Allihn and Graham Condensing Models for Optimum of Solvent Recovery. *Environmental Journal of Environmental Studies*. Vol. 4 No 5 December 2017. ISSN: 1110-457X. Faculty of Environmental Design, Ahmadu Bello University, Zaria-Nigeria. Pp 89-97
- Jekada, J. Z. Gonah, C. M., Garkida A. D. and Ladan, Z. (2017<sup>B</sup>). Comparative Studies on Graham Glass Condensing Models Types “As” an “Bs” for Extraction of Natural Dyes from *Lawsonia Inermis*. *International Journal of Advanced Research and Publications (IJARP)* <http://www.purp.org/online-paperspublishingnov.2017.html>. Volume 1 issues 5 November 2017 Edition, Pp 369-373
- Keyser, P. T. (2014). *Alchemy in the Ancient World from Science to Magic*. Illinois Chemical Studies xv2Pp2-26.
- Kotz, J. C., Treichel, P., and Weaver, G. C. (2005). *Chemistry & Chemical Reactivity*. Thomson Brooks/Cole. ISBN 053439597X. Pp234-239
- Kolmetz, K. (2011) *Distillation Column Selection and Sizing Engineering Design Guideline Practical Engineering Guideline for Process Plant Solution*, KLM Technology group, h03-12 blockaromia, Riverria Collovilla Taman Tampoi Utama. Jala Sciperkasa 2, 81200 John Bahru Malaysia.
- Luque de Castro, M.D and Garcia, L.E. (2000). *Soxhlet Extraction ; Environmental Applications Soxhlet Extraction 2701*. University of Cordaba, Cordoba, Spain. Academic Press, 2000.
- Syed, M. G; Shoukat. A, Pradeep. K.M; Bhat. S.J.A; Syed .H; Shamsul .H; Igbal. J; Gazala. Q; Asif.H. S, Shakeel. A. M, Khan P. A., Sarfaraz. A.W. and Raja A.S.M (2015). Eco-friendly Dyeing of Wool and Pashmina Fabric (fruits cups) Dye and Salix Alba L. (wood extract) Mordant. *Journal of Applied and Natural Science* Volume 7 (1): Pp 138-143; Division of Environmental Sciences, She-e-kkamir University of Agricultural Sciences and Technology of Kashmir, Shalimar-190025 (J&K), INDIA.
- Tahir, P. M. B; Musgrave, O. C., and Ashaarit, T. (2005). Determination of Polyphonic Content of Bark Extracts for Wood Adhesive. *Holzforchung* 56, pp 67-272.
- Zahurul, M. H. (2011). *ME 415 Condensers & Cooling Towers*. <http://teacher.buet.ac.bd/zahurul/>. Retrieved 05/02/2015.