VALORISATION OF WASTE CHICKEN FEATHERS: Utilisation as a binder in the forest products industry

by

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- Methodology
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- Conclusions
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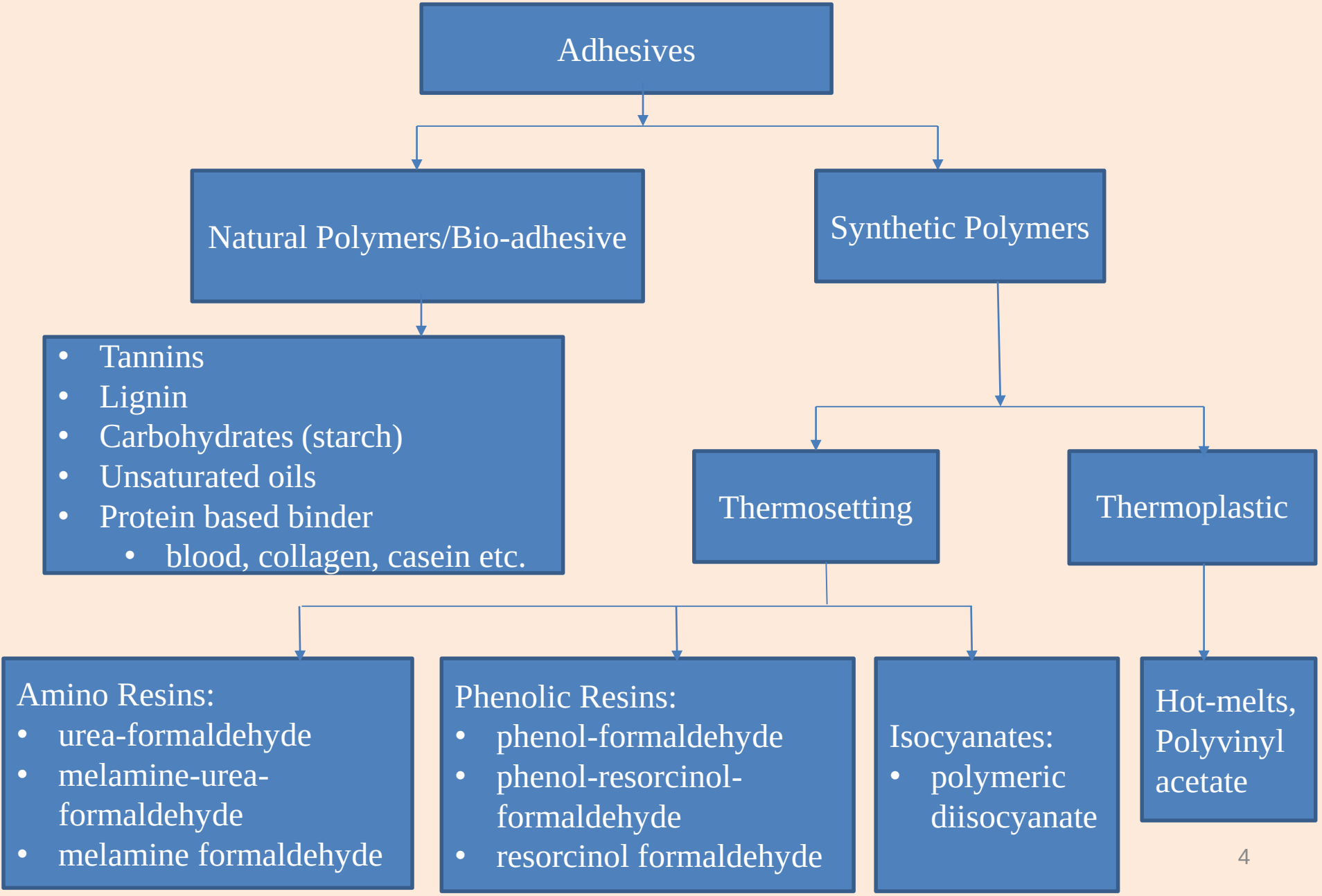
Introduction

Wood composites

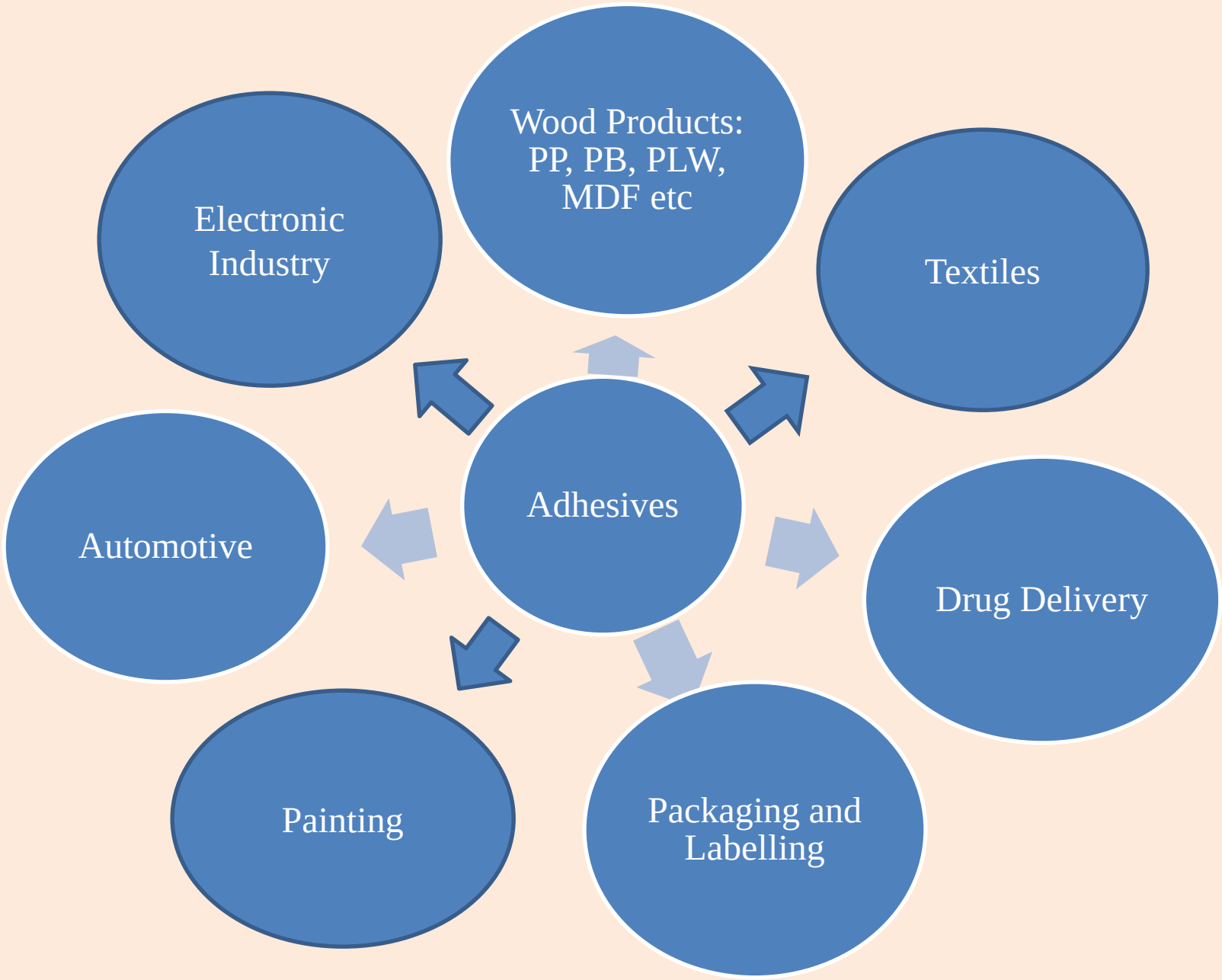
Key player in the efficient utilisation of the timber resources

- An adhesive or binder is a compound that *adheres or bonds two items together and resist their separation*.
- Adhesives may come from either *natural polymers (glue) or synthetic polymer*

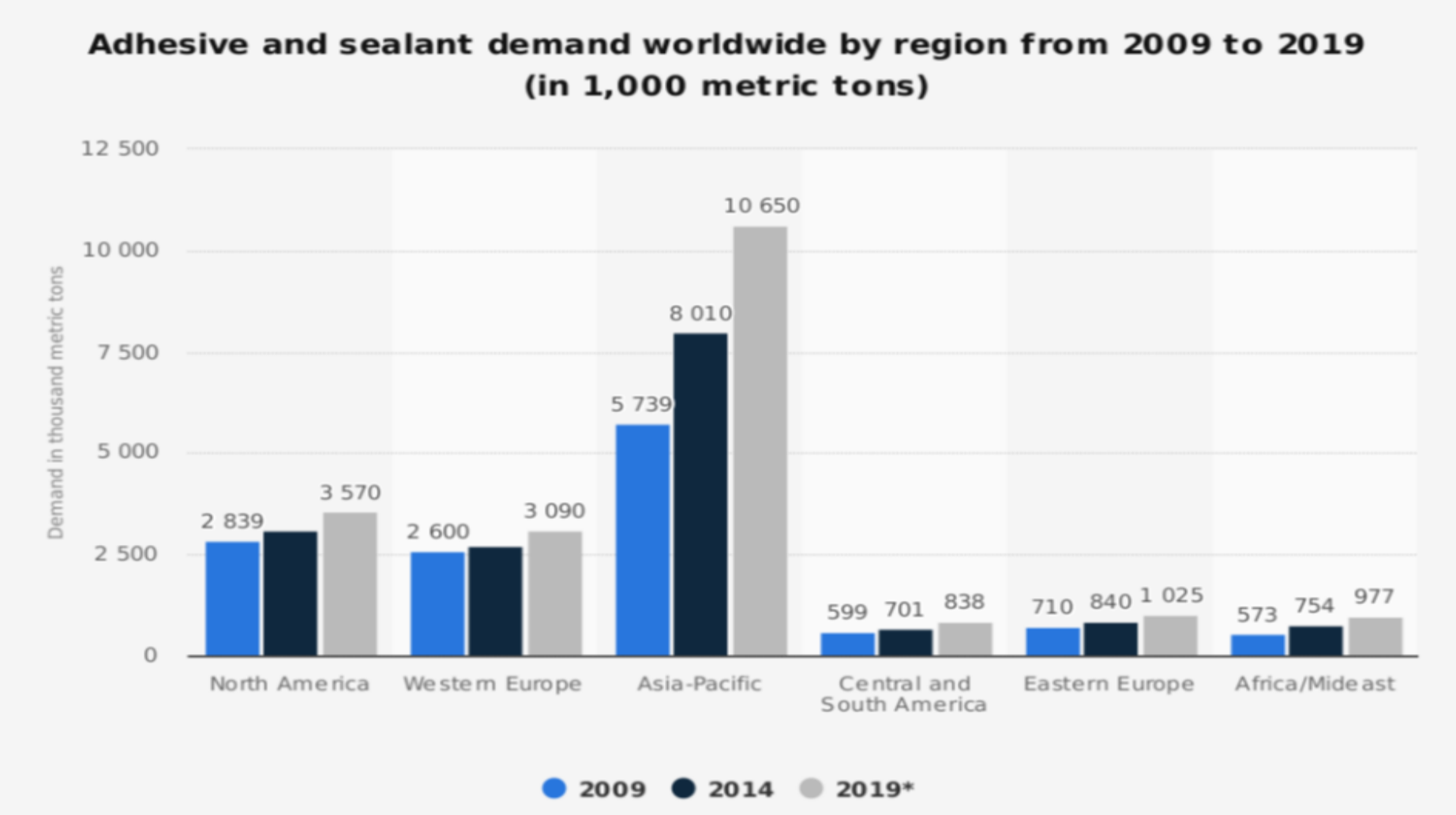
Classification of Adhesives



Application of Adhesives



Demand for adhesive



- Wood product manufacturers: more than 65% by volume of the adhesives used and demand in the world.
- The use of adhesives is a daily occurrence.

Why bio-adhesives???

- Bio-adhesives were predominantly used in the wood products industry, but displaced by synthetic adhesives.

- Synthetic adhesives are formaldehyde emitters
  - ***Causes environmental pollution and***
  - ***Is detrimental to human health.***

- This has led to renew interest in the natural sources of wood adhesives

Bio-based adhesive

- Covers any *polymeric or pre-polymeric monomer/ oligomer derived from nature/non-mineral origin* that will cure permanently to form a durable bond.

- Can be used **as it is, or after a little modifications** to reproduce the behaviour and performance of synthetic resins (Pizzi, 2006).

- **Problem:** *Poor performance* in relations to *water resistance and mechanical strength.*

Aims and Objectives

- The general objective of this study is to utilise chicken feathers as a source of binder in the wood products industries,
  - To chemically modify chicken feather keratin protein for adhesive production
  - To assess addition of chicken feather protein in the production of binders, e.g.,
    - Formaldehyde-free binders
    - Phenol-free binders
  - To evaluate the binding performances of the produced adhesives in various applications such as particleboard, MDF and paper products.
  - To optimize production technologies for the binders

Chicken Feathers as a Source of Protein

Feathers are;

- Considered a “waste” material
- Comprised of about 91% protein (keratin), 1% lipids, and 8% water
- Hydrophobic in nature
- Fibrin proteins that are much easier to hydrolyse than globulins present in soybeans

Why Chicken Feathers???

- Bio-resource with high protein content
- Worldwide poultry consumption has been increasing everyday generating a large amounts of feathers.
- An estimated 20 billion pounds of chicken feathers are available globally each year as a by-product of the poultry industry.
- In South Africa, the consumption of poultry meat result in generation of - **258 x 10^6 kg of chicken feathers annually**.

Benefits of Chicken Feather-based Adhesives

- The use of these adhesives has the potential to reduce the cost of production of panels as well as the selling price.

- It will reduce the health hazard caused by the formaldehyde emission from formaldehyde-based adhesives.

- It will also reduce the environmental pollution caused by chicken feathers disposal.

Previous work from literature

- Two feather protein hydrolysis methods (with and without presence of phenol during hydrolysis).
- Two formaldehyde/phenol molar ratios (1.8 and 2.0) at three pH levels (9.5, 10.5, and 11.5).
- The resin formulated with feather protein hydrolyzed in the presence of phenol, using a F/P ratio of 2.0, and at a pH of 10.5 performed well.

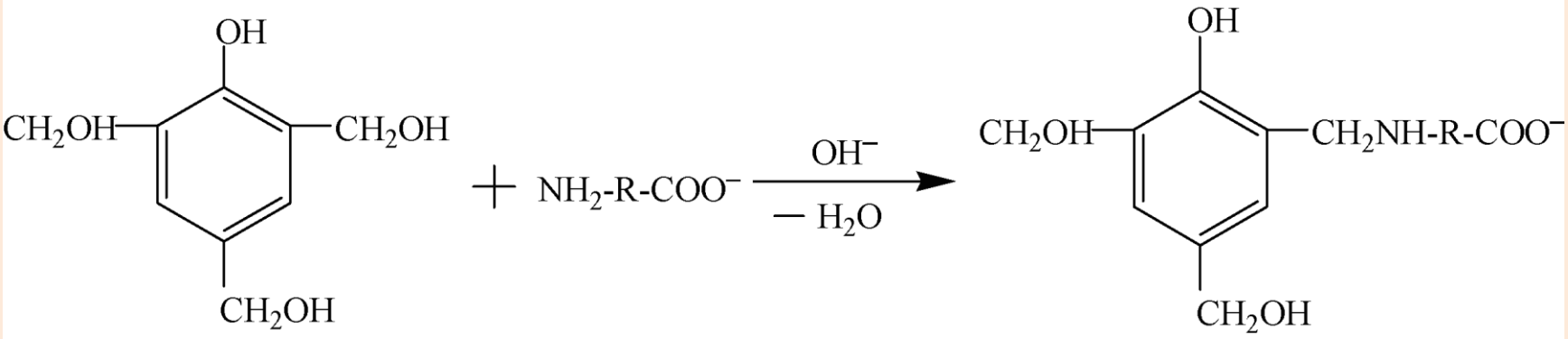


Fig1 : A possible reaction pathway (Jiang et al, 2008)

Problems from the previous work in the literature

- It was a preliminary work
- Formaldehyde was used
- And the formaldehyde emission level was not mentioned.
- Phenol was used which is also toxic to the environment.

Methodology

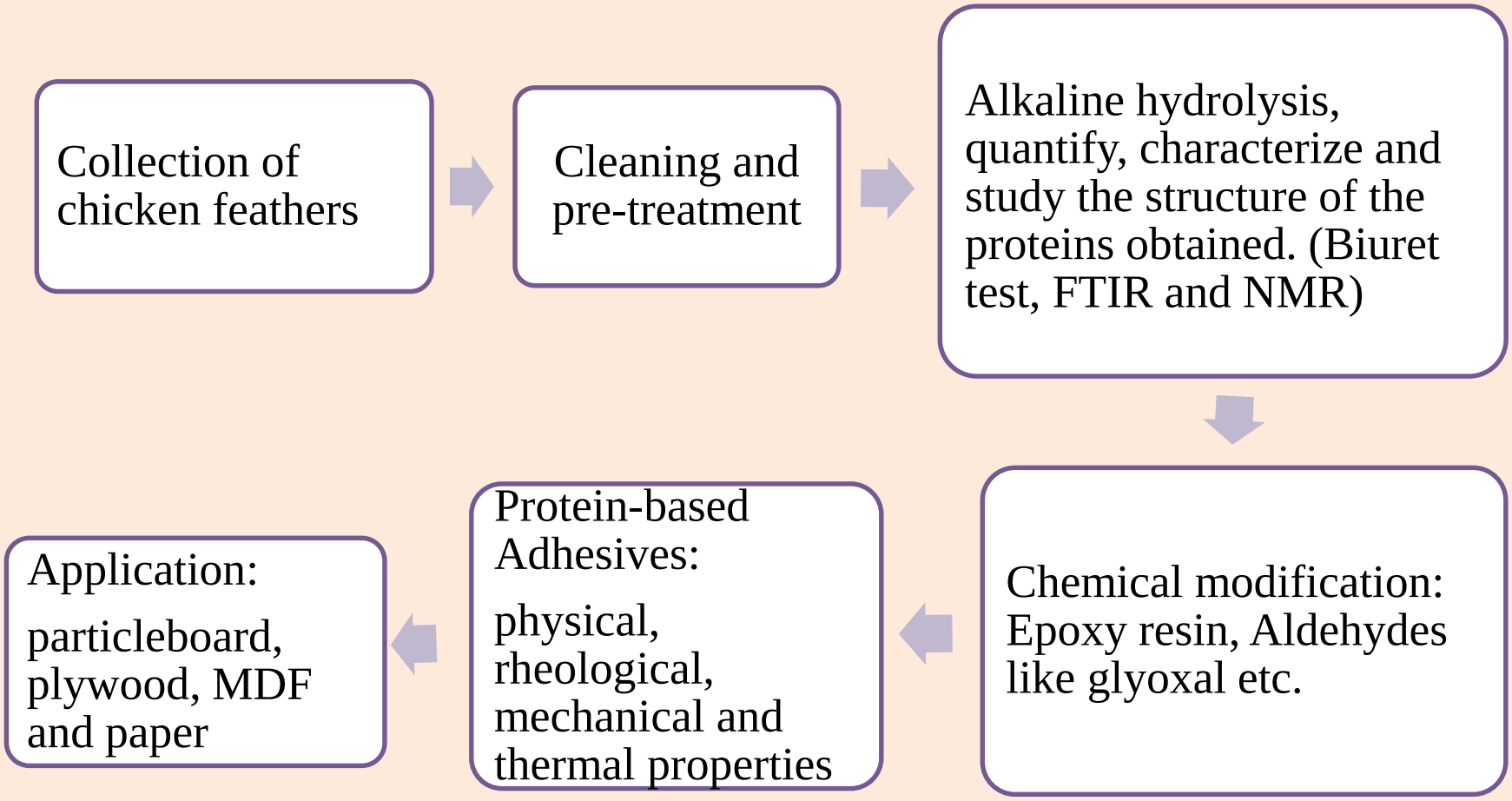


Diagram 1: Flow chart for chemical modification of chicken feather keratin protein for binder production

Chicken Feather Proteins

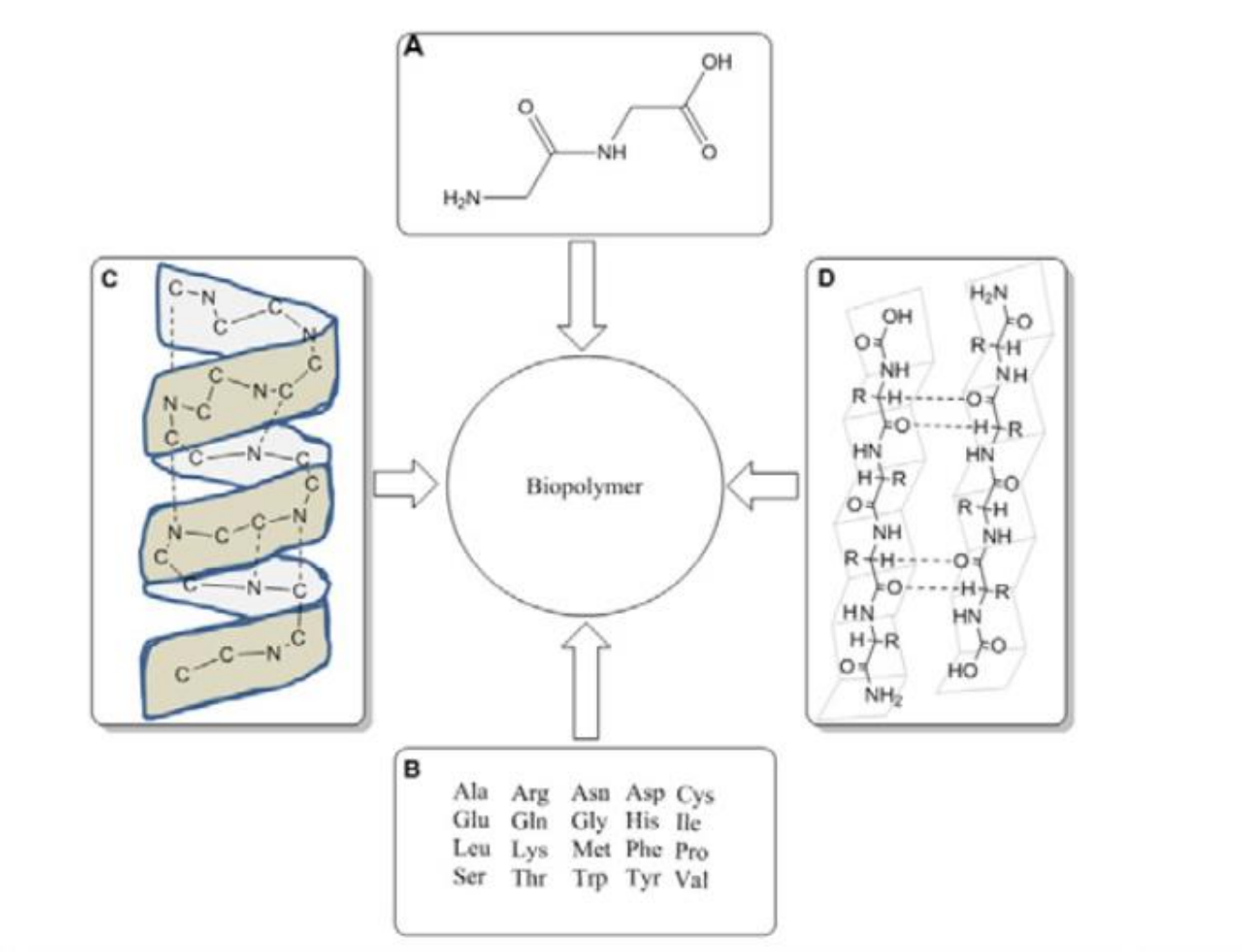


Figure 2: Schematic diagram of different components of keratin; (A) polypeptide single unit, (B) amino acid sequence, (C) α-helix, and (D) β-Sheets conformations of keratin protein. (Khosa et al, 2013)

Results and Discussion

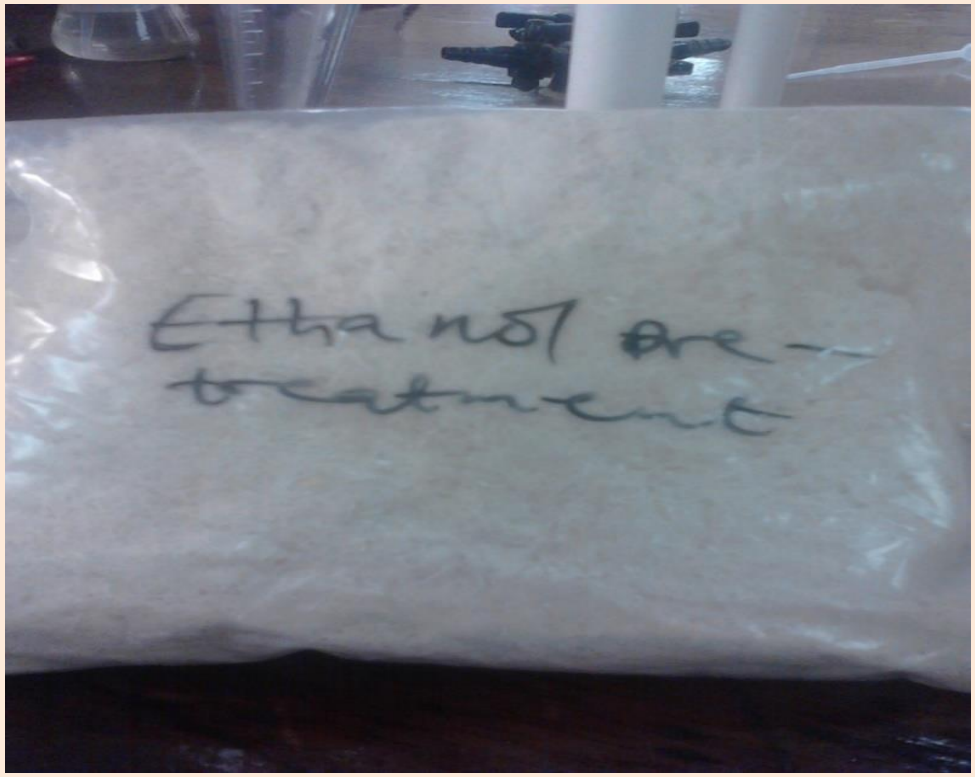


Fig 2: Chicken feathers (cleaned, treated)

Fig 3: Chicken feathers treated with ethanol, milled and ground

Keratin Protein Extraction using Alkaline Hydrolysis Method

Fig 4: Alkaline hydrolysis Ratio 1:5

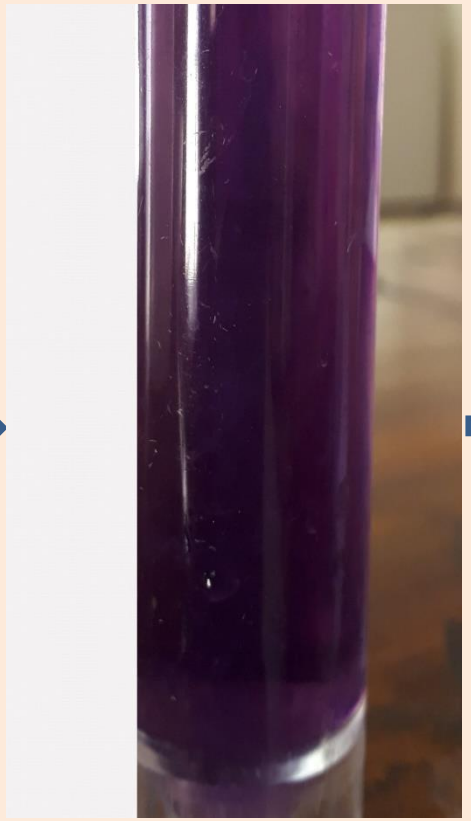


Fig 5: Biuret test

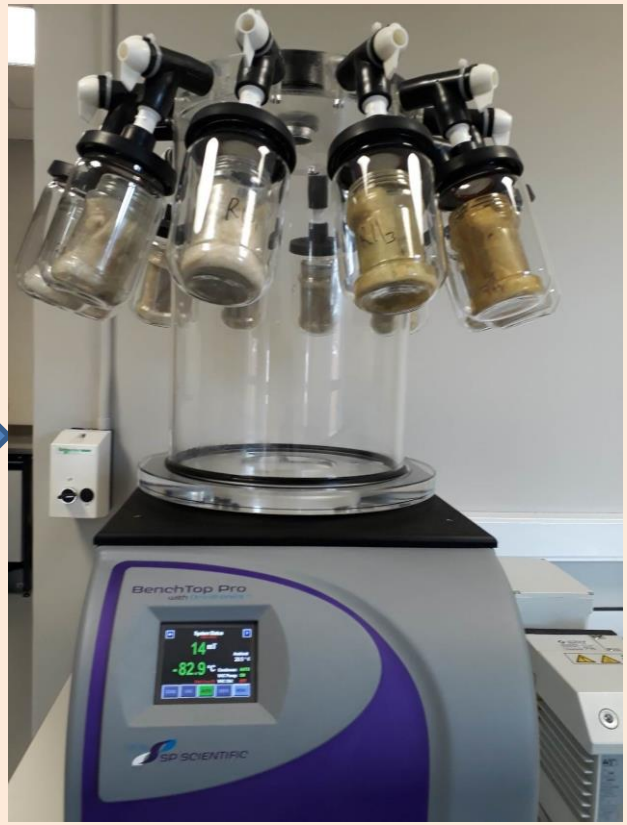


Fig 6: Freeze-drying

- This preliminary results show that, it is possible to extract keratin proteins from waste chicken feathers, the next step is to modify the proteins for binder production.

Experimental Design using Design Expert

Factors	Response 1: Dissolution Yield (%)	Response 2: Protein Yield (%)
A:Time (90-120 mins)		
B:Temperature (80-90 oC)		
C:NaOH (1,5- 2 %)		
D:NaHSO3 (0- 1 %)		

FT-IR Result

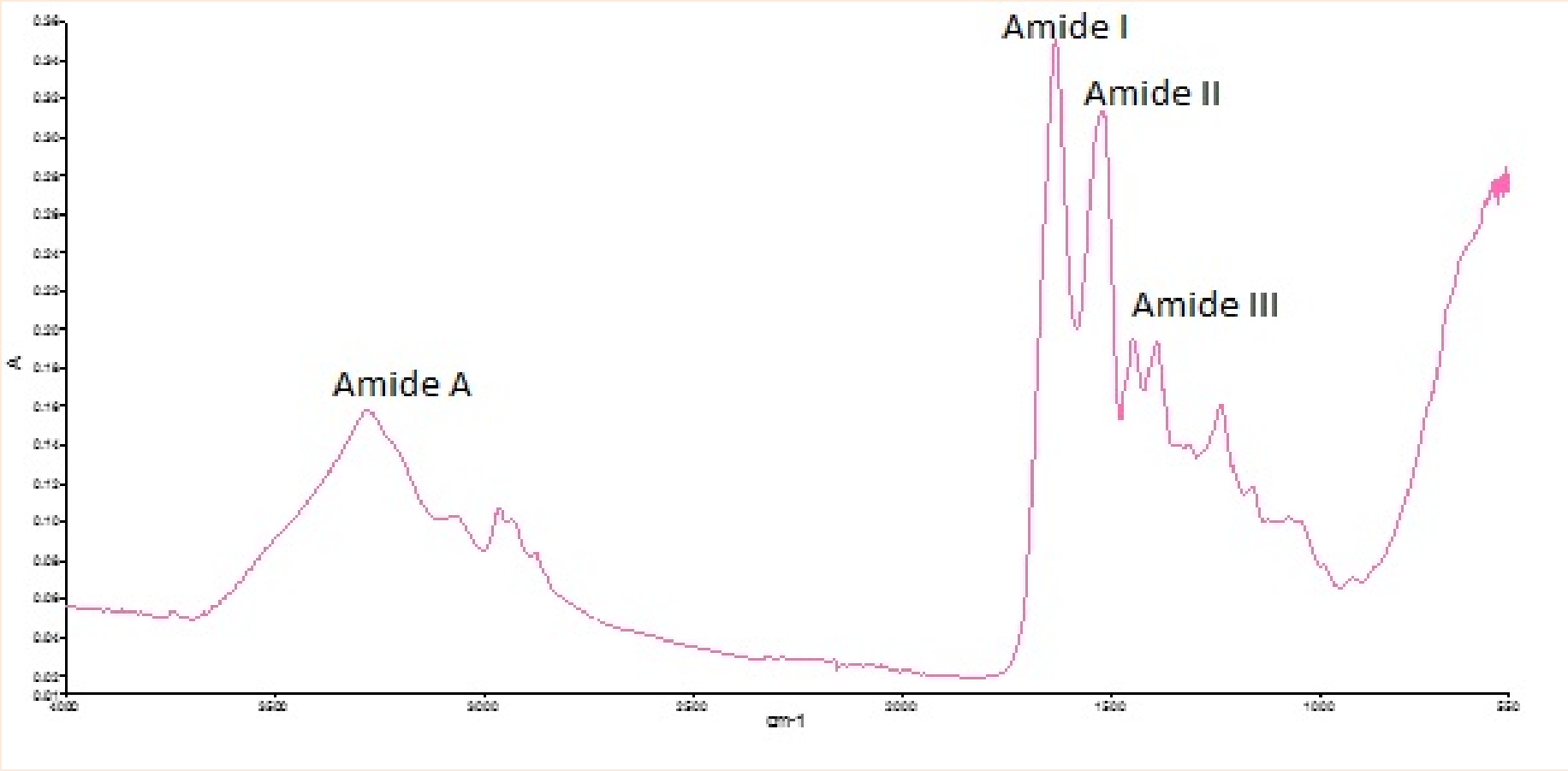


Diagram 3: FTIR Spectra for keratin protein from Alkaline hydrolysis

FT-IR spectra for Keratin from the literature

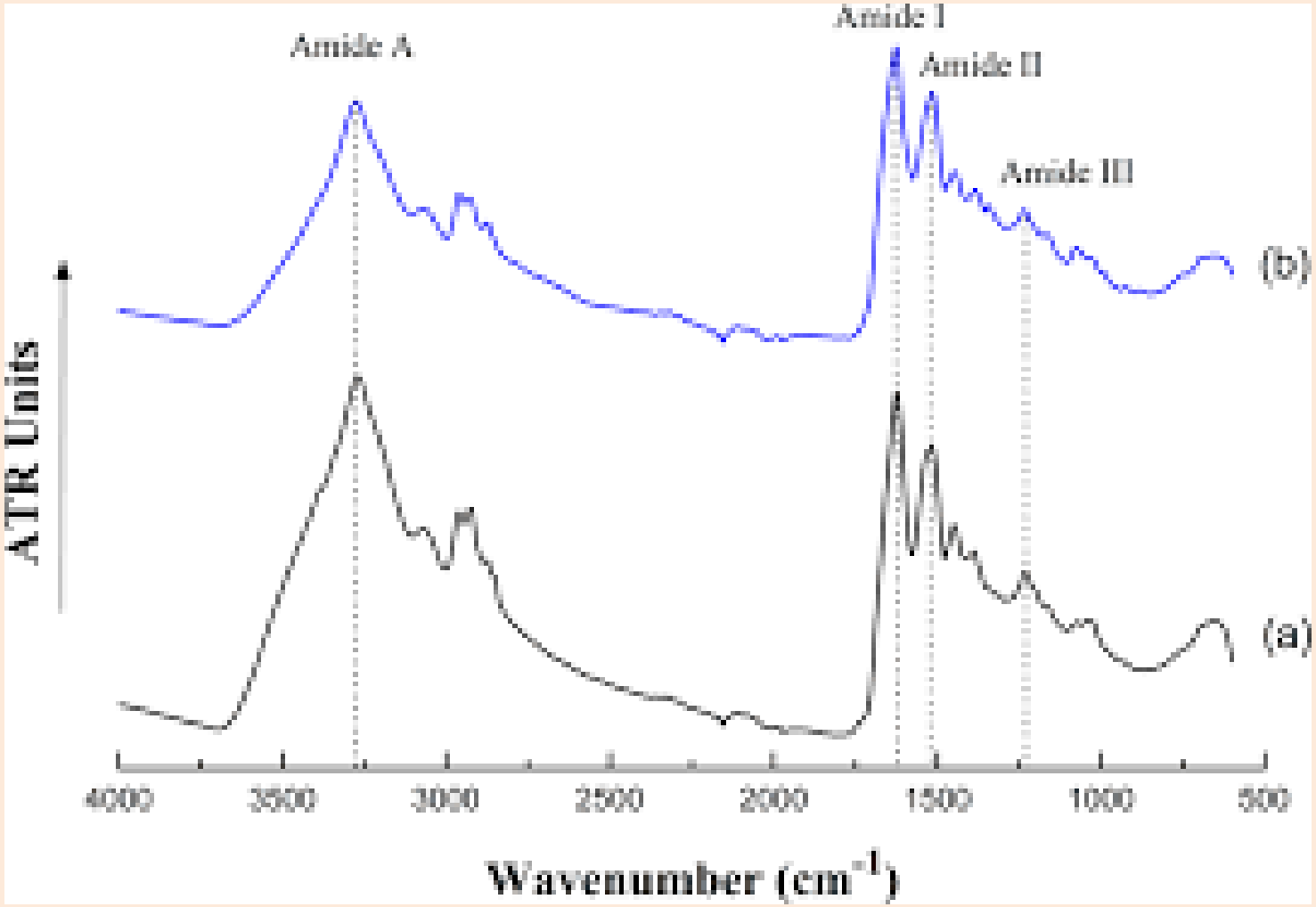


Diagram 4: FTIR Spectra from the literature (Azila et al, 2014).

ANOVA

ANOVA for Response Surface Reduced Linear model		
Analysis of variance table [Partial sum of squares - Type III]		
	p-value	
Source	**Prob > F**	
Model	0,0376	significant
A-Time	*0,0514*	
B-Temperature	*0,0810*	

Chicken Feathers Dissolution Yield

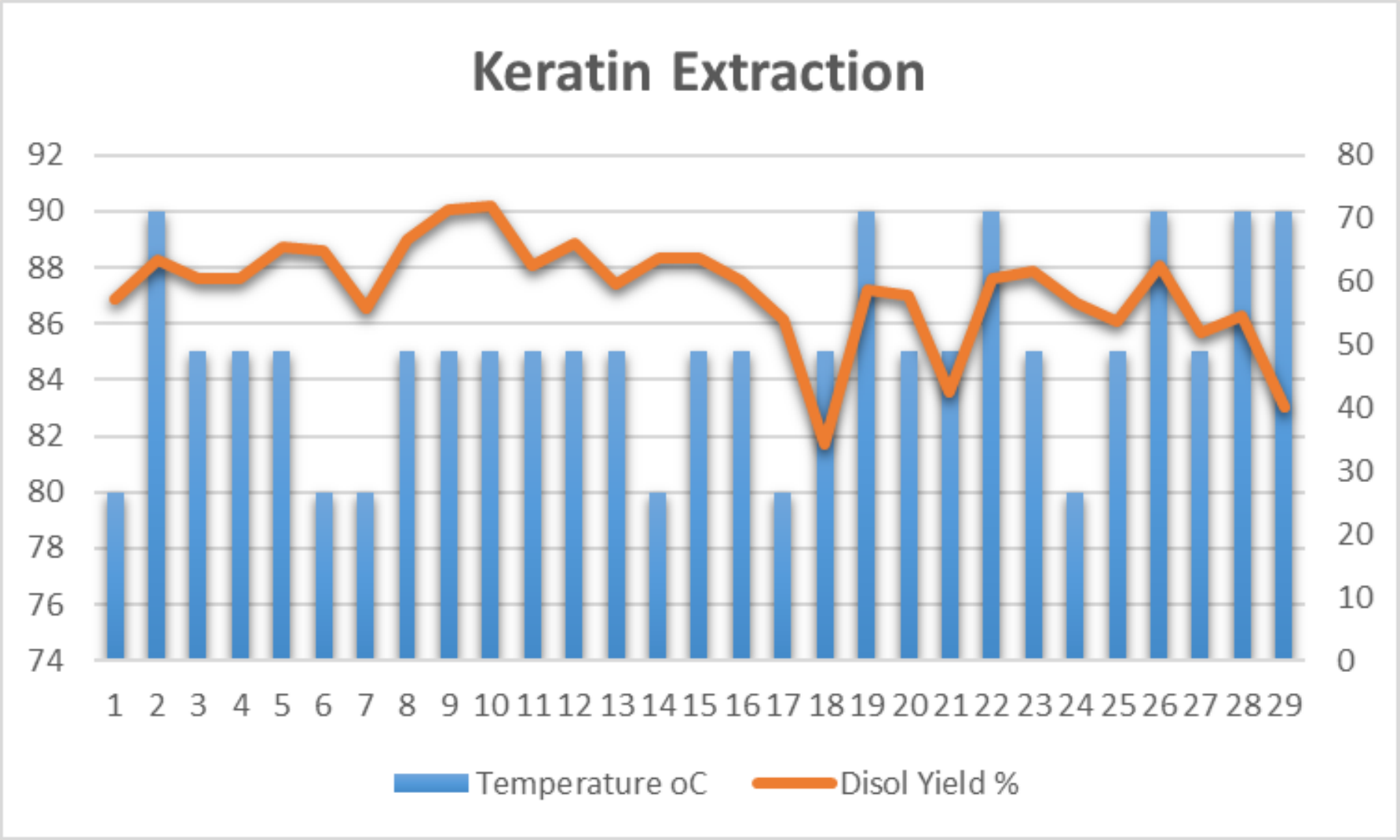


Fig 7: Effect of Temperature on the dissolution yield

Chicken Feathers Dissolution Yield

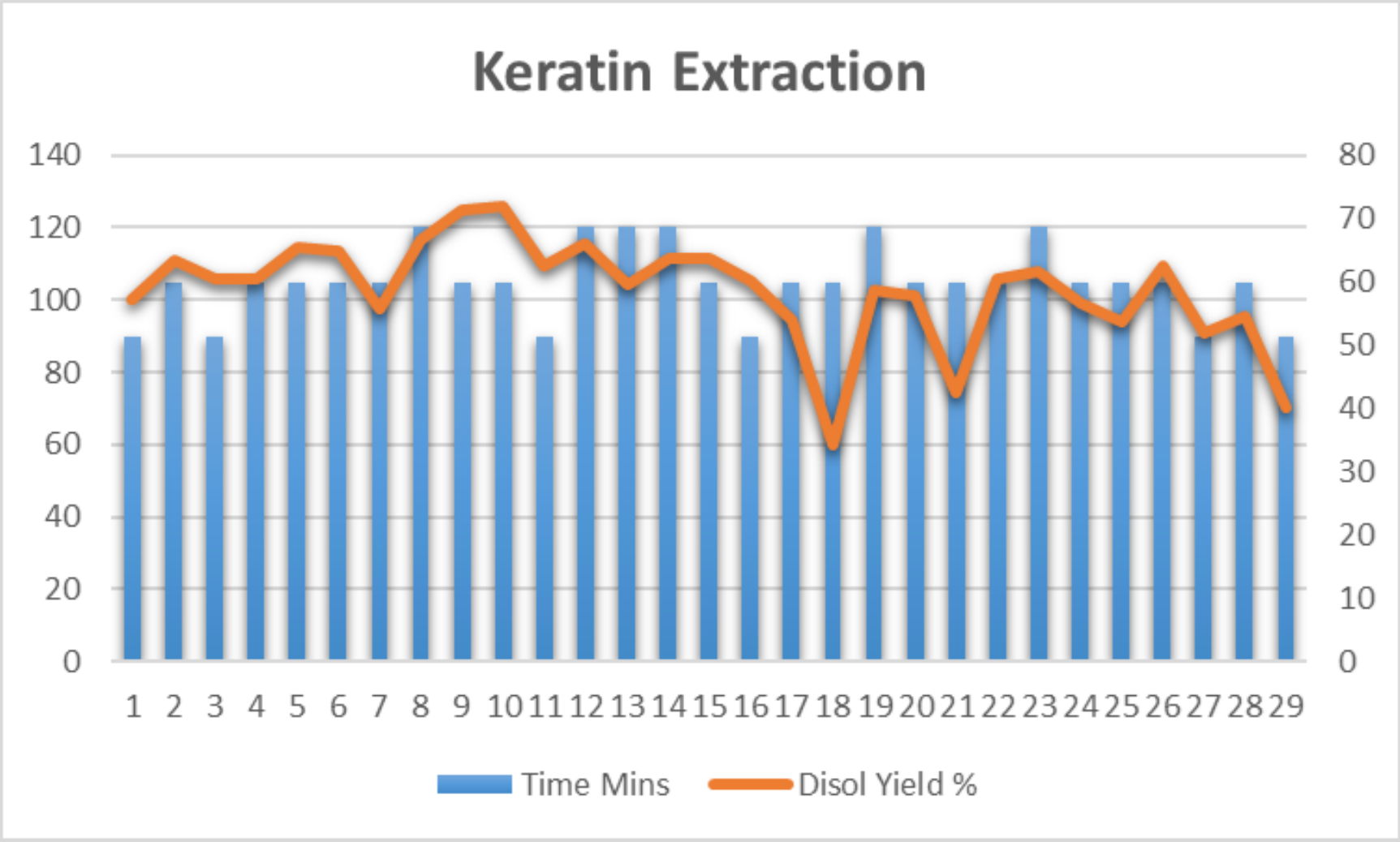


Fig 8: Effect of Time on the dissolution yield

Chicken Feathers Dissolution Yield

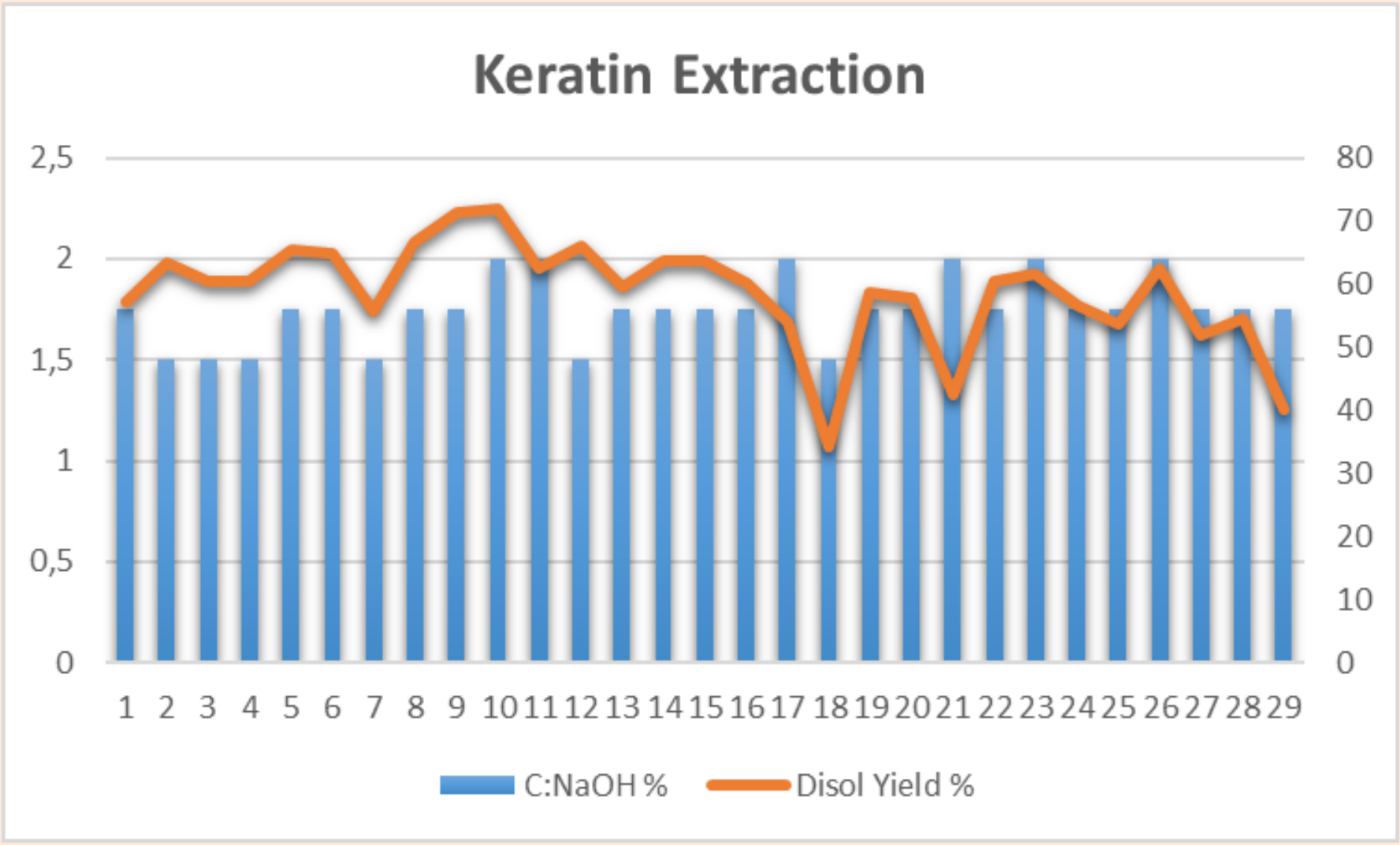


Fig 9: Effect of NaOH on the dissolution yield

Chicken Feathers Dissolution Yield

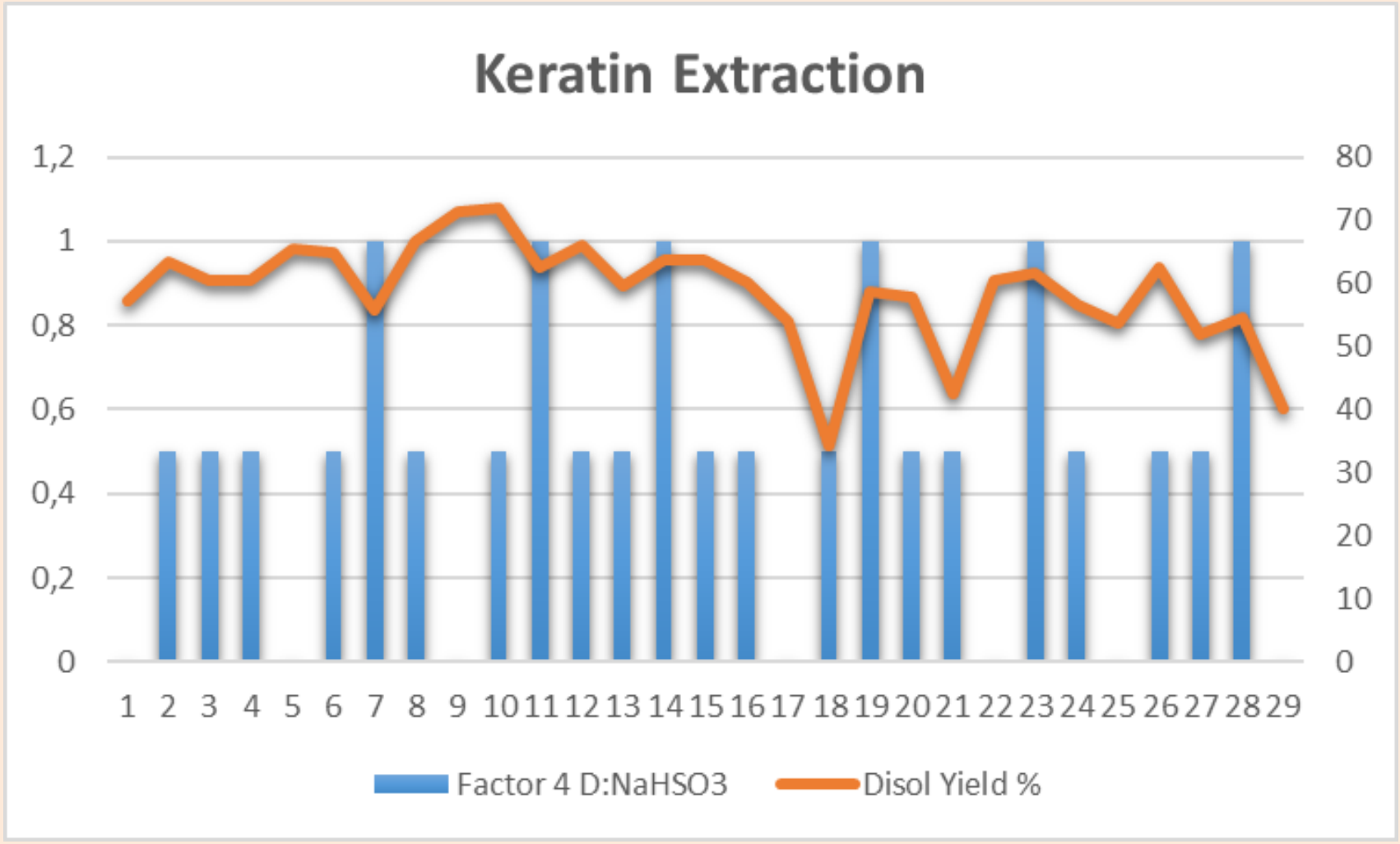


Fig 10: Effect of NaHSO3 on the dissolution yield

Keratin Extraction

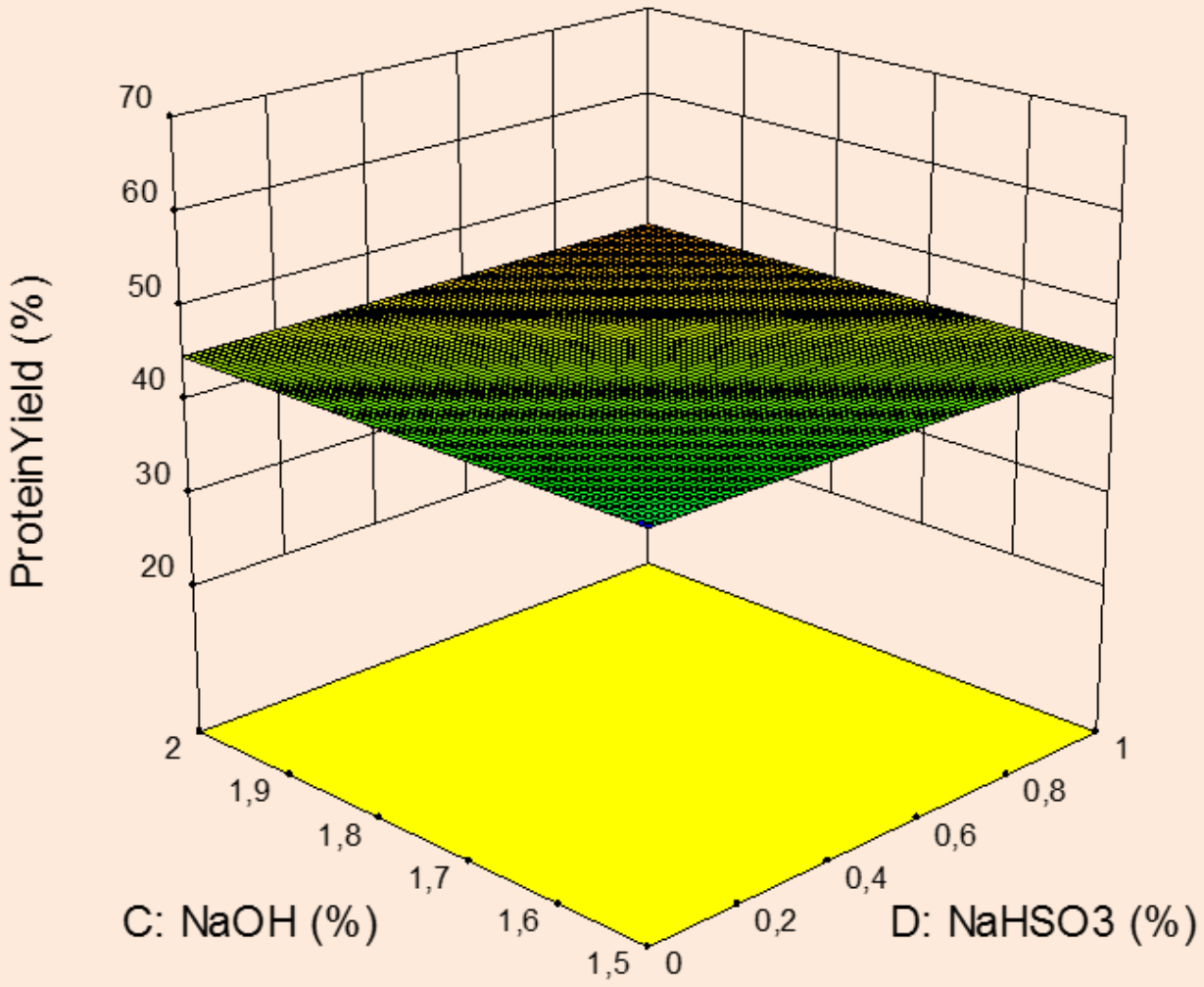


Fig 11: Effect of chemicals used on the Protein yield

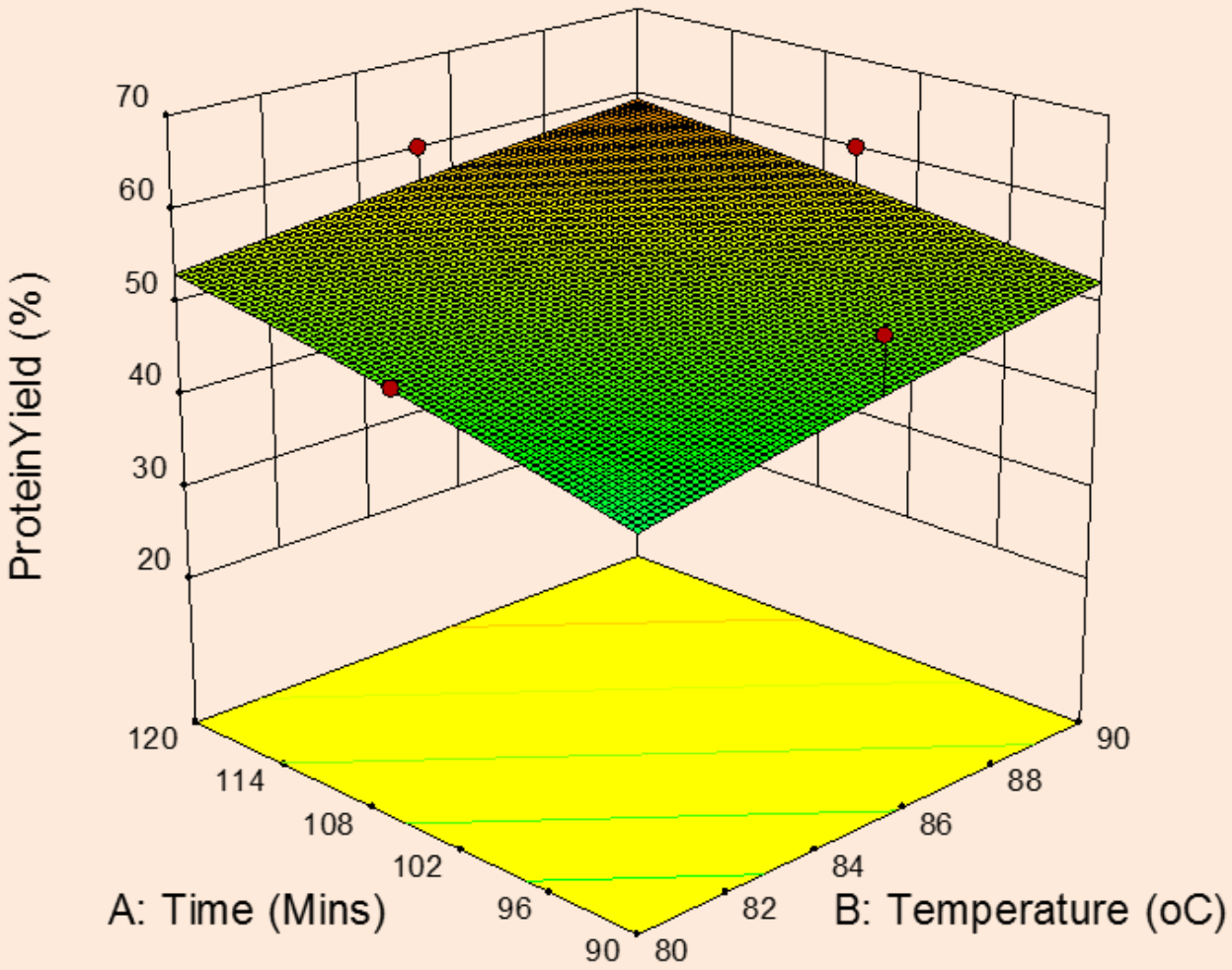
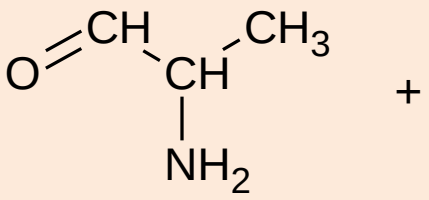


Fig 12: Effect of Time and Temperature on the Protein yield

Keratin Protein

N	S
%	%
12.706	0.537
12.026	0.496
12.197	0.510
12.745	0.703
13.310	0.725
13.077	0.781
12.383	0.541
12.296	0.661
12.890	5.40
13.001	0.963
13.045	0.747
11.610	0.662
12.755	0.712
12.258	0.785
12.224	0.563
11.883	0.668
12.663	0.578
12.449	1.11
11.543	4.79
12.040	4.20
14.196	2.06
15.118	2.17
13.393	2.36
14.398	1.84
14.970	1.66
15.099	8.82
13.997	1.83
14.256	1.80
14.180	1.64

Binder Production(Trial)



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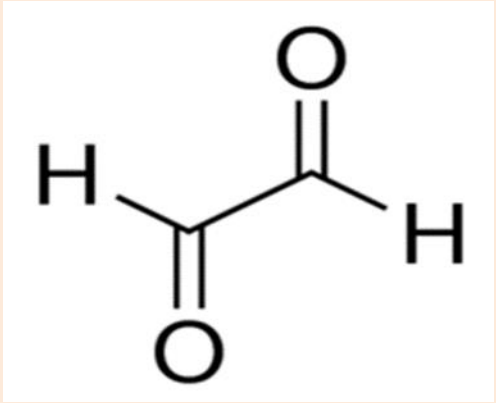

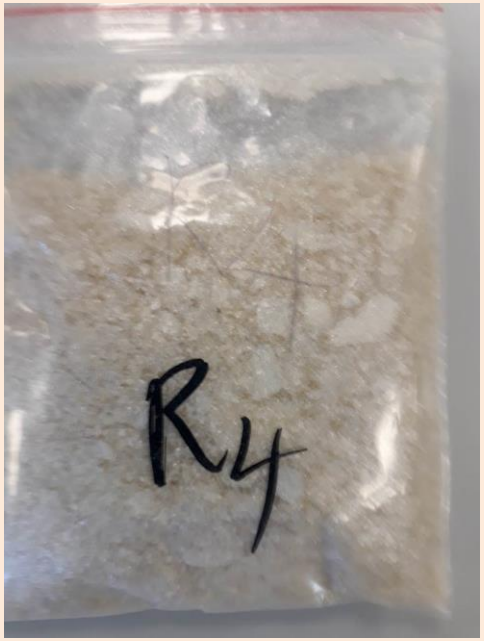

Chicken feathers protein powder

Glyoxal

Conclusion

- It is possible to solubilized Chicken Feathers using *Alkaline Hydrolysis and have high protein yield*
- Retain the *secondary structure* of the protein
- It is feasible to utilized Chicken Feathers proteins as a bio-binder in the wood composite Industry

- Further work: Design a detail experiment for the synthesis of Chicken Feathers based bio-binder, characterization and application.

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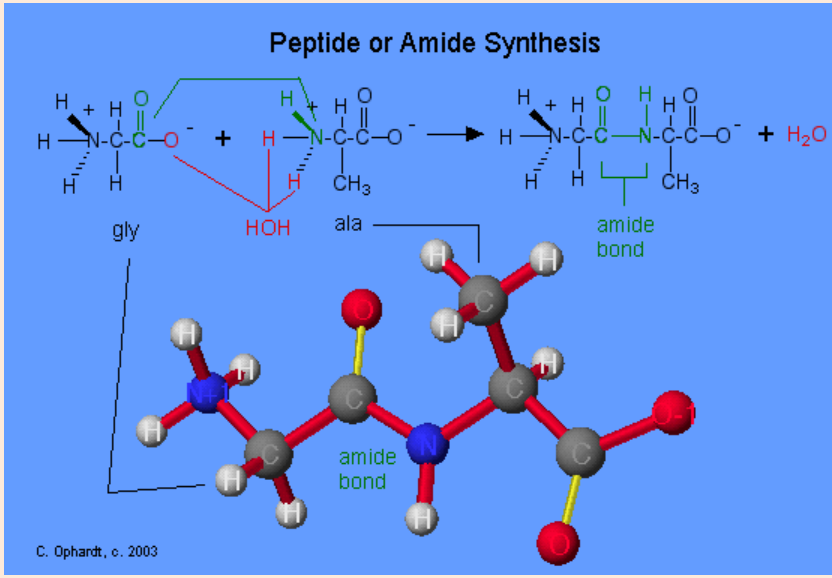

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